ANL/NE-17/35

Subject Matter Expert Workshop for the Use of Municipal and Commercial Equipment for Radiological Response and Recovery: Argonne National Laboratory Workshop Summary Report

Nuclear Engineering Division

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Subject Matter Expert Workshop for the Use of Municipal and Commercial Equipment for Radiological Response and Recovery: Argonne National Laboratory Workshop Summary Report

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Abstract

This report summarizes a workshop held in Argonne National Laboratory to identify the equipment and databases that support methods that might be available for emergency operations. Specifically, the Environmental Protection Agency and the Department of Homeland Security identified a need to develop response and recovery guidance to mitigate the effects of a radiological or nuclear release that compromises recovery in an urban environment or at a critical infrastructure. The objective of this workshop was to discuss the experience of the first responder community and environmental remediation specialists to identify equipment and methods that may be used to accomplish various missions summarized under five broad support goals. This document summarizes the comments from the Argonne National Laboratory meeting. Based on the findings and input from a series of such workshops, we plan to develop "best practices" for use of equipment responding to and recovering from a wide-area radiological incident.

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1. Introduction

The National Urban Security Technology Laboratory (NUSTL) of the Department of Homeland Security (DHS), in collaboration with the U.S. Environmental Protection Agency's (EPA's) National Homeland Security Research Center and Argonne National Laboratory (ANL), sought to identify the equipment and databases that support methods that might be available for emergency operations to mitigate the effects of a radiological or nuclear release that compromise recovery in an urban environment and at critical infrastructure. The purpose of this study is tounderstand what types of equipment might be available and in evaluating such equipment for its utility in mitigating a nuclear or radiological release event. We understand that it will be impossible to initiate activities other than life-saving operations and securing a site for the safety of the people and the responders during the immediate, emergency phase of a response. Instead, we were concerned with the period of time between securing the site and a federally organized cleanup effort. This period might be significant, as we have learned from the Japanese and their response time frame for the nuclear disaster at the Fukushima Daiichi nuclear power plant. Processes and procedures for a timely response to a wide-area contamination event are not currently established around the country. Instead, response planning of this type is still in the very early stages, and this project is part of this early work.

We connected with relevant emergency management and homeland security offices at the city, state, and regional level—including major cities across the United States—and with federal agencies. We compiled and evaluated recommended approaches to dealing with potential contamination scenarios and the types of equipment assets that would/could be invoked to assist in the response. We sought information on how various subject matter experts (SMEs) might approach the problem and possibly make recommendations on how current equipment reserves can be best used or modified to improve their utility in a radiological or nuclear mitigation response.

As part of initial steps toward gathering the expert opinions of a swath of subject matter experts across areas of emergency response and infrastructure operations, we held workshops and invited subject matter experts to reflect regional variability, ranging from differences in local practices to extremes in weather. The first Workshop was held at Argonne National Laboratory in the Chicago area on March 16-17, 2017. Workshop participants were presented with, and discussed in detail, five (5) support goals associated with radiological response and recovery. These are: 1) Survey and Monitoring, 2) Mitigation of Received Dose to First Responders, 3) Decontamination (gross and final), 4) Waste Management, and 5) Containment of Water, Wastewater, and Other Wastes. Training needs were also discussed.

The Argonne workshop attendees are listed below.

Invitee name	Organization	Invitee name	Organization
United Kingdom		Illinois	
Rosina Kerswell	UK Government Decontamination Services	Lance Wilson	IL EM
Sara Casey	UK Government Decontamination Services	Glen Lyman	Chicago Fire Department
Lynn Cooper	Studsvik		
Karl Hughes	Cavendish	FEMA	
Gordon John	Amec Foster Wheeler	James Cullen	FEMA R5
Lorimer Fellingham	Nuvia	Paul Pruesse	FEMA R5
US EPA		Air Force	
Katrina McConkey	EPA/Contractor	Keith Sanders	US Air Force
Matthew Magnuson	EPA		
Sang Don Lee	EPA	Argonne National Laboratory	
Eugene Jablonowski	EPA R5	Mike Kaminski	Nuclear Engineering
William Steuteville	EPA R3	David LePoire	ANL Radiation Assistance Program
Lyndsey Nguyen	EPA Vegas	Joseph Adduci	ANL Radiation Assistance Program
Michael Worth Calfee	EPA	Will Jolin	Nuclear Engineering
Anne Mikelonis	EPA	George Mosho	ANL Radiation Assistance Program
Lukas Oudejans	EPA	George Vucovich	Risk and Infrastructure Science Center
Tim Boe	EPA	Judy Chiarreli	Risk and Infrastructure Science Center
John Archer	EPA	Jodi Leiberman	Global Security Studies
Scott Hudson	EPA		
US DHS			
Benjamin Stevenson	DHS S&T – NUSTL		
Orly Amir	DHS S&T – NUSTL		
Gladys Klemic	DHS S&T – NUSTL		

Several introductory presentations at the Workshop were given to introduce the project and provide a historical summary of our global experience in wide-area urban radiological decontamination techniques. The titles are given below and copies of the presentations can be provided upon request (please email Michael Kaminski, Kaminski@anl.gov).

- *DHS S&T, Benjamin Stevenson, Program Analyst, National Urban Security Technology Laboratory (NUSTL)*

- *Research in Radiological Remediation, Matthew Magnuson, EPA National Homeland Security Research Center*
- *Fukushima Remediation Lessons Learned, Sang Don Lee, EPA National Homeland Security Research Center*
- *Wide Area Decontamination History and Project Introduction, Mike Kaminski, Argonne National Lab.*

2. Scenarios for Support Goals

For this Workshop, we generated a number of hypothetical missions or "scenarios" that were grouped under the five support goals, as detailed in the workbook distributed to SMEs around the country and to participants of the Workshop (see Section 3). Responses to these goals are summarized in Section 3. The scenarios in the tables should not be considered exhaustive, but were intended to spark conversation and promote out-of-the-box thinking of potential uses of equipment. The equipment used to address these example scenarios was not intended to be applied in the field during life-saving operations. Instead, the intended timeline was as soon as possible to reduce dose to workers or the general public or to protect or restore critical infrastructure for its rapid return to service. The common initial state for all scenarios is that contamination has been spread over a wide area of the city. First responders have identified the presence of radioactive contamination and have completed their response protocols to provide a preliminary assessment of the radioactive levels. Life-saving operations have been completed. In this stage of operations, aside from unpredictable weather and precipitation, we expect the following activities in the impacted area:

- People, vehicles, and objects have moved/are moving in and out of the contaminated areas.
- Remediation for critical infrastructure is urgent (e.g., water utility, energy utility, transportation, medical, fire station, and government facilities).
- Regular activities (business, school, etc.) are still underway in the non-evacuated but contaminated area.
- Hotspots are being identified and remediated.
- Remediation strategies are being developed for the evacuated area.

3. Participant Responses to Scenarios for Support Goals

The participant responses to the scenarios in Section 2 are provided in the tables in Appendix A and captured below.

3.1 Survey and Monitoring

We wish to monitor the contamination levels in affected areas, perhaps for an extended period, to understand the dose to workers and residents and the evolving change of contamination level over time. What types of municipal and commercial equipment can be used to enhance the survey and monitoring of contamination? (Note: we will not assess traditional survey monitoring equipment such as film badges, portable survey monitors, and gamma-ray spectrometers already in place in response vehicles or personnel since these are specialized pieces of equipment that are already accounted for in the procedures of the first responder communities.) Examples include using air filters from garbage trucks, delivery trucks, and police and firetrucks that have well-defined routes that can be tracked using GPS to understand the spatial distribution of airborne contaminations[1] or attaching traditional survey equipment to vehicles that have well-defined routes to facilitate survey efforts. The scenarios under Survey and Monitoring are described in Table 1.

Table 1. Description of Survey and Monitoring Scenarios

Support Goal:	**Survey and Monitoring**
	Scenario Description
Scenario 1	We wish to measure on a regular basis the contamination levels in areas initially affected by contamination (that is, fallout deposits of radioactive material) in terms of external dose at the street level (that is, the radiation levels at the street from external gamma and beta radiations). What equipment can be used to provide such measurements, and what tools do we have to develop maps of contamination with this data?
Scenario 2	We wish to measure on a regular basis the contamination levels in areas initially affected by contamination (that is, fallout deposits of radioactive material) in terms of external dose within residences and businesses (that is, the radiation levels within the homes, apartments, or business offices from external gamma and beta radiation). What equipment can be used to provide such measurements, and what tools do we have to develop maps of contamination with this data?
Scenario 3	In the areas affected by contamination, we wish to measure on a regular basis the resuspended contamination levels at the street level (that is, the contamination attached to airborne particles that are suspended in the air as a result of vehicle travel, pedestrian travel, or wind). What equipment can be used to provide such measurements, and what tools do we have to develop maps of contamination with this data?
Scenario 4	We expect tracking of contamination from the initial deposit area to other areas via vehicle and personnel transport. What equipment and methods can be used to identify these contaminated egress routes? For instance, can vehicles originating from a contaminated zone be tracked using existing highway cameras?
Scenario 5	How would the above equipment and methods differ if the contamination occurred at a critical infrastructure such as a hospital, wastewater reclamation facility or drinking water treatment plant, airport, or communications centers (for example)?
Scenario 6	Other ideas related to monitoring and procedures: i. Can we use traffic cams to evaluate the most used thoroughfares? ii. Can we use traffic cams/red light cams to track individual vehicles for follow-up survey for those most severely contaminated? iii. Can resulting dose maps be used to determine the best evacuation route to reduce the amount for exposure and facilitate the tracking of radioactive contamination.
Scenario 7	Do you have other thoughts or specific questions based on your experiences in your geographical area related to this topic?

Summary of Survey and Monitoring

Scenario 1, 3, 4, and 5 focused on monitoring dose and airborne contamination at the street level or critical infrastructure and received many of the same responses. It was noted that for critical infrastructure priority would be given to resources and assets. For Scenario 1, 3, 4, and 5, the discussions on survey and monitoring centered on using well-established agencies and techniques. For

[1] Filter analyses will identify potential "hot" travel routes but cannot identify specific location unless active sampling is employed.

instance, the Federal Radiological Monitoring and Assessment Center (FRMAC) is going to have an SME role in initial characterization and a need for continuous monitoring in places that may not have initial characterization or that may have been cleaned initially. Monitoring over a long period needs to be planned (i.e., long-term environmental data management program). Perhaps, monitors could be used on vehicles that have routes that are already in place. It is important to make those plans ahead of time. Equipment exists to track measurements and tie them into GPS and data management programs. NUSTL recently published a relevant document on portal monitors [System Assessment and Validation for Emergency Responders (SAVER) Portable Radiation Portal Monitors Market Survey Report," March 2015]. Also, EPA has data management tools used for the Flint, Michigan drinking water response (2015). Therefore, there are tools already in place that can be used for assessment.

Examples of municipal equipment that could serve as a platform for measurement of contamination (Scenario 1 and 3) are buses, postal vehicles, sanitization trucks, and snow removal trucks because there are tools (e.g., apps) in use that already track their movements. However, the SMEs cautioned that the sensor affixed to vehicles, etc., must have a pedigree that can be trusted. Coupling the interfaces, maps, and apps that exist with radiation detectors and radiation responders may be useful.

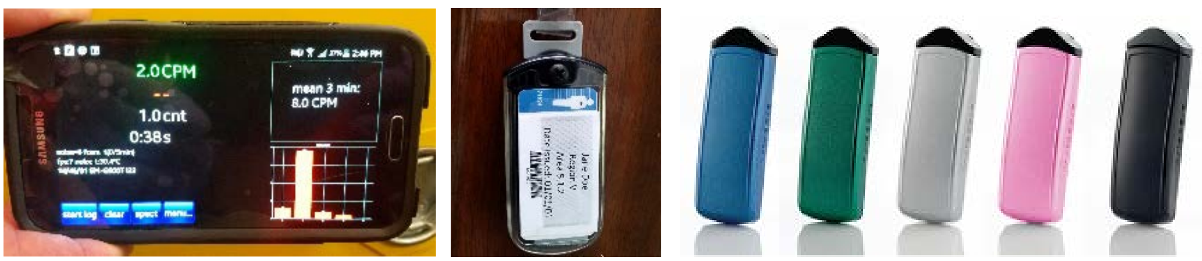
Regarding Scenario 2, it was generally believed that monitoring within homes and individual businesses will be more difficult. It is worth emphasizing a common caution expressed by the group; we must have confidence in the dose data that are disseminated to the public. For data collected by expert organizations like FRMAC, this is not an issue. However, if we place detection systems onto municipal vehicles, for instance, then we must have confidence in their response. Ensuring the confidence in these systems will not be as difficult (because the operators can be properly trained and the monitors can be fixed onto the vehicle, tracking can be automated, and data can be transmitted without user input) as monitoring options given to individuals for their homes or businesses. Options for collecting data from households are included below and would represent in most cases a significant amount of low fidelity data, but may represent a very thorough cross section of the environment, including within homes and businesses. Examples of radiation monitoring devices include the following (see also Figure 1):

- Thermo-luminescent dosimeters (TLDs) on bus routes, animals, etc., could build up a picture of contamination in an area. It would be worth considering lower fidelity and higher standard validation techniques that can be used together (such as the use of smart phones or personal detection devices).
- A USB dosimeter (Instadose by MIRION Technologies, $25) could be used for tracking. These are great for shift work, are cheap enough to deploy to many types of vehicles, animals, and structures, and can be given to people to track their dose and feed the data into a central database.
- Pager-type devices that have Bluetooth capability could be automatically connected to software architecture like RadResponder Network (www.radresponder.net/). Workers could send data through a pager while they are working. After the Fukushima reactor accident, the public purchased their own detectors and reported the data through social media, and then eventually someone mapped the data. The government used it as a tool/opportunity to validate contamination in areas. We need to be prepared for this type of public response.

- Smart phones (10 μSv/hr) could also be used for radiation monitoring.

It was noted that the Chicago Fire Department (FD) capabilities include personal radiation detectors (PRD) and carbon monoxide meters on all crews (in and out of houses/structures), and firefighters log dose every day as part of their procedure. Some people would not leave contaminated areas, so crowdsourcing them to wear a dosimeter may be a good idea.

Region 5 of the EPA has been working on indoor mapping techniques. They have instruments that can use LIDAR scanning to view and map out interiors and have radiation equipment attached that provides indoor GPS style mapping capability. They also have tools developed for lead-contaminated homes and tablet applications tied into ArcGIS. They are developing ways for doing X-ray fluorescence (XRF) measurements. This could be adapted for radiation level determination.



A B C

Figure 1. Radiation Monitoring Options: A. Smart Phone Radiation Detector, http://www.ansto.gov.au/AboutANSTO/MediaCentre/News/ACS049898; B. Thermoluminescent Dose Meters; C. USB-type radiation detectors, https://www.mirion.com/products/occupational-monitoring-services/instadose-dosimetry-services/instadose-dosimetry-services/ (image C courtesy of Shutterstock).

In Scenario 4, we are interested in tracking contamination that may be moved by vehicles. Aside from the methods mentioned above for monitoring contamination, the conversation dwelled on methods to control such cross-contamination. Tacky mats, vehicle wash-down, portal monitors, and airborne area monitoring through unmanned aerial vehicles (UAVs) or helicopters were mentioned.

We did not have sufficient time to collect responses to Scenarios 6 and 7 from Workshop participants but did receive responses from the UK collaborators (see Appendix A).

3.2 Mitigation of Received Dose to First Responders

We wish to reduce the radiation dose burden to response personnel. What types of municipal and commercial equipment can be used to carry out gross decontamination of contaminated surfaces and to contain and prevent the resuspension and tracking of contamination either through the effects of wind or vehicle transport during the mitigation phase of the response to reduce the dose burden to first responder teams? Examples include using fireboats from the Port Authority to knock down radioactivity levels near the shore or dump trucks and bobcats to spread mulch and gravel across roadways to reduce the spread of contamination during vehicle transport. Note that "gross decontamination" is a type of decontamination that is conducted with the goal of reducing contamination levels. This reduction may not meet final cleanup levels but may be useful to mitigate some public hazard or contain contamination. The scenarios under Mitigation of Received Dose to First Responders are described in Table 2.

Table 2. Description of Mitigation of Received Dose to First Responders Scenarios

Support Goal:	**Mitigation of Received Dose to First Responders**
	Scenario Description
Scenario 1	We have identified that airborne contamination is a significant source of radiation dose to unprotected people. Given that the contamination after settling is primarily found on horizontal surfaces (e.g., streets, walkways, parking lots, urban green spaces), reducing the potential for resuspension is a potentially important goal. Through prior research, we have identified materials such as gravel, mulch, and sand as effective means of reducing resuspension if the material can be laid down over the contaminated surface. How would such material be distributed over an area of several linear blocks? How would such material be distributed over an area of several square miles?
Scenario 2	We have identified that airborne contamination is a significant source of radiation dose to unprotected people. Given that the contamination after settling is primarily found on horizontal surfaces (e.g., streets, walkways, parking lots, urban green spaces), reducing the potential for resuspension is a potentially important goal. Through prior research and experience, we have identified that washing the surfaces with fresh water is effective in removing contaminated particles from surfaces, thereby reducing the dose in the immediate area. How would fresh water be distributed over an area of several linear blocks? How would fresh water be distributed over an area of several square miles? How do the methods change if we need to distribute the water over vertical surfaces, such as the facades of buildings?
Scenario 3	We have identified that airborne contamination is a significant source of radiation dose to unprotected people. Given that the contamination after settling is primarily found on horizontal surfaces (e.g., streets, walkways, parking lots, urban green spaces), reducing the potential for resuspension is a potentially important goal. Through prior research and experience, we have identified that washing the surfaces with water containing salt (for example, seawater or salty water from water softener units) is effective in removing contaminated particles and fixed contamination from surfaces, thereby reducing the dose in the immediate area. How would we generate the salt water and distribute it over an area of several linear blocks? How would we generate the salt water and distribute it over an area of several square miles? How do the methods change if we need to distribute the salt water over vertical surfaces such as the facades of buildings?
Scenario 4	How would our proposed method of addressing Scenarios 1-3 change if the contaminated area is located sufficiently close to the ocean coastline or other navigable waterway such that maritime equipment and methods can be used?
Scenario 5	We have identified that airborne contamination is a significant source of radiation dose to unprotected people. Given that the contamination after settling is primarily found on horizontal surfaces (e.g., streets, walkways, parking lots, urban green spaces), reducing the potential for resuspension is a potentially important goal. Through prior research and experience, we have identified that applying a layer of sprayable polymer coating with the consistency of wet paint (for example, outdoor paints and epoxies such as those designed for roadways or other paved surfaces) to the surfaces is effective in containing contaminated particles. How would we distribute this polymer coating material over an area of several linear blocks? How would we distribute it over an area of several square miles? How do the methods change if we need to distribute the sprayable coating over vertical surfaces such as the facades of buildings?

Table 2. (Cont.)

Support Goal:	Mitigation of Received Dose to First Responders
	Scenario Description
Scenario 6	How would the equipment and methods in Scenario 1-3 and 5 differ if the contamination occurred at critical infrastructures such as a hospital, water reclamation facility, or drinking water plant, airport, or communications centers (for example)?
Scenario 7	We have identified that airborne contamination is a significant source of radiation dose to unprotected people. Given that the contamination after settling is primarily found on horizontal surfaces (e.g., streets, walkways, parking lots, urban green spaces), reducing the potential for resuspension is a potentially important goal. An area of concern is covered in contaminated debris and loose particles. In some areas, the debris is substantial and can be removed by bulldozer-type equipment. In other areas, the debris material is such that it can be swept and vacuumed. How would you approach the problem?
Scenario 8	Regardless of scenario, how would the above equipment and methods differ if the contamination occurred along egress routes that are needed to transport people away from the affected area (for example, major highways)?
Scenario 9	Do you have other thoughts or specific questions based on your experiences in your geographical area related to this topic?

Summary of Mitigation of Received Dose to First Responders

The majority of the discussion focused on Scenarios 1-3, the distribution of materials as an effective means of reducing resuspension and/or removing contaminated particles and fixed contamination from surfaces. Scenario 1 focused on spreading solid granule-type material to cover contaminated dust and debris, and Scenario 2, 3, and 5 focused on washing the contaminated surfaces with fresh or salty water and covering the surfaces with a polymer coating. Scenario 4 asked if options change if the contamination were near navigable waterways. Scenario 6 was concerned with contaminated dust/debris at critical infrastructure, and Scenario 7 with physically removing contaminated debris and dust by sweeping or vacuum. Scenario 8 specifically addressed contamination on egress routes.

There were several discussions around using salt or a salt-water solution. It was mentioned that there are EPA studies demonstrating that salt is not good for shielding radiation, but is a good suppressant and will reduce resuspension. Salt could be spread in a solid form, allowing rain to mix with it to make a solution. It was agreed that a salt-water solution is better than rain alone. If spreading is decided as a solution, a cost analyses would need to be done on seawater vs. onsite mixing. Participants referenced a proprietary study performed by the United Kingdon that showed dry salts to have no effect on the fertility of soil. However, when applied as saline, the solution killed the vegetation and caused more dust to aerosolize from barren soil.

Additional materials discussed are listed below:

- Fire retardant provides resuspension protection, but will leave residues and produce cleanup challenges.
- Tackying agents used at mountain top removal are readily available and inexpensive.
- Dust suppression that also incorporates seeds helps promote grass growth, which will knock down suspension long term.

Some of the options discussed for application of these suppressants for wide-area contamination included:

- Parking lot/pavement spraying equipment.
- Miscellaneous construction site equipment to spray roads and buildings.
- HEPA filter fitted street cleaners to reduce initial contamination.
- Firefighting aircraft/helicopters/crop dusters to knock down heavy contamination before responding.
- Use of firefighting hoses and personnel.

Figure 2 contains examples of salt application equipment. Figure 3 contains examples of water pump and misting/fogging equipment.

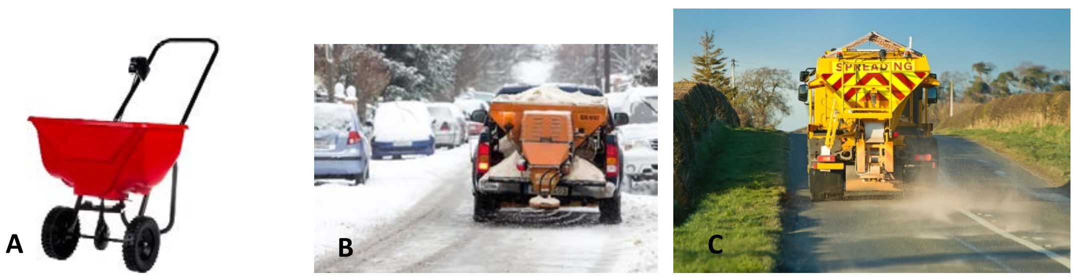


Figure 2. Salt Spreading Equipment. A. Small Drop Spreader, https://www.amenity.co.uk/drop-spreaders/bannerman-drop-spreader.html; B. Medium Salt Spreader, http://www.snowexproducts.com/product/v-maxx-sp-7550; C. Large Salt Spreader, http://pdf.archiexpo.com/pdf/aebi-schmidt/combination-machines-spraying-spreading-stratos-combi-soliq-plus/67143-142135.html#open (courtesy of Shutterstock).

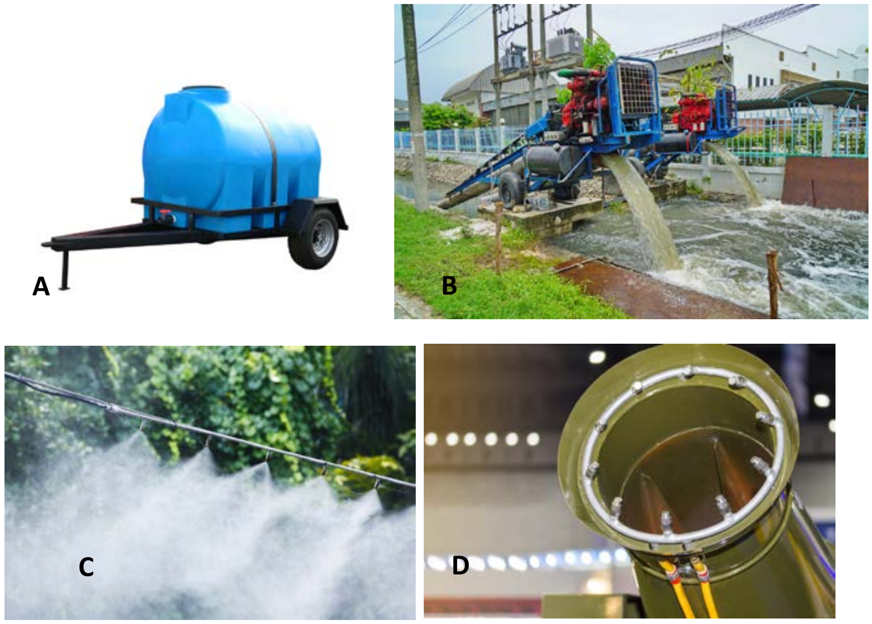


Figure 3. Water and Misting/Fogging Equipment: A. Portable Water Trailers, https://www.polymaster.com.au/catalogue/industrial/fire-fighting; B. High Capacity Water Pump, https://www.hycos-firefighting.com/enclosures/trailers/; C. Small Area Misting/Fogging, https://www.aliexpress.com/store/product/Free-shipping-10m-33-Outdoor-Garden-Patio-Misting-Cooling-System-10pcs-plastic-mist-nozzles-garden-irrigation/102850_1159292517.html; D. Medium Area Misting/Fogging; https://www.buyamag.com/fogging_misting_humidifiers.php (courtesy of Shutterstock).

It is important to consider dry/hot climates where misting surfaces to reduce resuspension may not be an option. The military has been using dust suppression technologies and equipment for a long time, especially for desert operations. The U.S. Air Force may have information on suppressants and application technologies.

The following questions were raised for the application of suppressants/washing agents: How often do we apply them? How much waste will be generated? Where are radionuclides going to end up? It was agreed that we need to acquire additional knowledge on application procedures, agent fate and transport, and waste generation.

It was noted that washing down surfaces, with any agent, will generate significant amounts of secondary waste in the form of contaminated liquids. Maybe initially, we cannot stop the runoff of water into the sewer system, but later we have to collect, store, and treat it. It will be critical to keep wastewater out of the sewage treatment plants where it can kill the bacteria. We need to work with wastewater and storm management locals to determine the best ways to contain and treat the waste. Containment options discussed included plugs to divert and control water flow, as well as sewer system bladders and expandable liners. Vacuum trucks and portable water pumps could be used to remove and transport contaminated liquids. Additionally, basins could be utilized for storm water/wash water. When cleaning is complete, the top layer of soil could be removed from the basin.

Debris and dust removal (Scenario 7) was discussed. A HEPA vacuum is necessary on dry debris removal machines to suppress dust. Also, a misting unit could be implemented before vacuuming. However, dust from debris removal is a concern even when the surface has been wetted. It was noted that HEPA vacuums in London (Litvinenko - polonium incident) did not work well on carpet and furnishing, and it was more effective to cut out carpet, bedding, etc. Additionally, recent EPA tests showed vacuuming to be ineffective on carpet, but effective for dry particles, even in the small size range. There may be some large-scale vacuum units that are used in the nuclear industry. In general, debris areas should be dampened down to reduce the generation of dust. Smaller materials could then be collected by either man-controlled HEPA vacuums, for example, or through use of municipal vehicles such as road sweepers.

It was mentioned that Japan identified hot spots as sludge and debris. The sludge and debris were removed from the storm water system as soon as possible by using shovels and vacuum trucks and were then dried and burned.

We did not have sufficient time to collect responses to Scenarios 8 (egress routes) and 9 (other thoughts not captured in the scenarios) from Workshop participants, but did receive responses from the UK collaborators (see Appendix A).

3.3 Decontamination (Gross and Final)

We recognized that decontamination methods can be more effective if implemented within days of a release rather than waiting months or years for the contamination to evolve chemically and physically, rendering it more difficult to remove. What types of municipal and commercial equipment can be used to carry out gross or final decontamination of contaminated surfaces? Examples include use of asphalt-milling machines to remove the top layer of road surfaces, bobcats to remove the top layer of vegetation or soil, and tillers to turn over contaminated soil. Note that "gross decontamination" is a type of decontamination that is conducted with the goal of reducing contamination levels. This reduction may not meet final cleanup levels but may be useful to mitigate some public hazard or contain contamination. The scenarios under Decontamination (Gross and Final) are described in Table 3.

Table 3. Description of Decontamination (Gross and Final) Scenarios

Support Goal:	Decontamination (Gross and Final)
	Scenario Description
Scenario 1	EPA studies identified that soil was a major source of contaminated material in decontamination effort in an urban environment. Prior research and experience suggest that by removing less than 5 cm (2 in.) of soil, nearly all the contamination can be removed. What equipment would be useful in removing a very shallow depth of soil from large urban green spaces such as playgrounds and open grass fields?
Scenario 2	Same as Scenario 1, except that we wish to identify equipment that would be useful in removing a very shallow depth of soil from smaller, discontinuous plots of urban green spaces such as front and backyards and garden areas.
Scenario 3	Hard, horizontal surfaces such as roads, walkways, and parking lots can trap radioactive contamination. Prior studies and experience shows that the contamination resides at or very near the surface of such hard materials (<1 cm or <0.5 in.). What equipment would be useful for removing contamination at the surface? What equipment would be useful in removing a very shallow depth of paving material? How does the choice of equipment and method change if many linear miles of surfaces need such treatment?
Scenario 4	As in Scenario 3, prior studies and experience show that the contamination on paved surfaces can be effectively reduced by washing these surfaces with water-based solutions. What type of equipment can be used to wash many linear miles of these paved surfaces and collect the washings?
Scenario 5	How would our proposed method of addressing the scenarios above change if the contaminated area was located sufficiently close to the ocean coast line or other navigable waterway or river system such that maritime equipment and methods can be used?
Scenario 6	Do you have other thoughts or specific questions based on your experiences in your geographical area related to this topic?

Summary of Decontamination (Gross and Final)

Scenarios 1–2 focused on identifying useful equipment for removing very shallow depth of soil from large urban green spaces (such as playgrounds and open grass fields) and smaller discontinuous plots of urban green spaces (such as front and back yards and garden areas). It was agreed that a good excavator will have no problems with removing 3-4 in. of soil well without mixing the soil. A range of standard construction equipment and municipal equipment could be used, such as excavators, sod/turf cutting machine, snow ploughs, and hand tools (e.g., spades). Potentially, various types of equipment in agriculture could be modified and fitted with scrapers. Vacuum tools/trucks could be used to decontaminate dry loose soil/dirt covered lands. Sod cutting machines will work for removal of grass on flat surfaces, but are not good for irregular surfaces or areas with tree roots. It is worth noting that during removal work in test ranges (very large, flat open spaces) contaminated with particulate forms of plutonium (in UK), equipment was decontaminated, except for scrapers and buckets, and went into commercial use.

One problem with removal of large amounts of soil is that sources of backfill will be limited, and if the removed soil is not replaced, drainage problems can occur. Is it more cost effective to remove the soil or cover it with more soil or rock, then come back at a later time to clean? Options other than top soil removal should be considered. In Japan, many farmers chose top layer removal, which ended up being problematic due to the removal of nutrients. The turnover of soil turned out to be the best practice. The farmers did have to treat the soil with more nutrients, but not as much as removal, and the radiation reduction was good. It was noted that for Chernobyl, deep plowing (up to 3 ft) was performed, and additives were used to fix the cesium (Cs) in the soil. Also, Chicago beaches have sand-sifting machines that remove the top layer, then sift and lay it back down. These could potentially be modified and include something that will bind with the Cs before laying the soil back down.

For Scenario 2, we addressed smaller discontinuous plots of urban green spaces, such as front and back yards and garden areas. Hand digging techniques may be effective. It was noted that some open landscape is hard and cannot be easily removed/scraped. Pressure washing of rock gardens or wiping of rocks (done in Japan) and use of hand scrapers to remove a thin layer of soil may be what is necessary, but is very time consuming. It was suggested that homeowners are going to do whatever they need to if they want to stay. An EPA study is currently looking at outdoor cleaning approaches for homeowners and should be published next year.

As a general thought, there is no simple answer for a wide area approach. It will be necessary to think outside the box. The time it takes to remediate will be very important as people will not return if it takes too long. If there is a risk for broken communities, then rebuilding vs. cleaning should be considered. It might be better to turn over the land to developers and let them redevelop and turn it into green space. However, this approach will increase the amount of waste. When making decisions, the amount of radiation people are willing to tolerate needs to be considered. Families living in Fukushima, where the contamination is at low levels, have learned to accept the new normal ambient radiation levels.

Regarding Scenario 3, equipment that would be useful for removing contamination at the surface was discussed. It was made clear that the exact response would depend upon the contaminated surface and the amount that needs to be removed. Some of the options discussed included high-pressure water wash with and without abrasive additives such as sponge blasting and grit blasting. Dry ice blasting and bubble technology were also mentioned. Conventional concrete shaving or asphalt surface shavers are prevalent, and vehicle-mounted planers or excavators may be appropriate. Smaller units such as hand planers, scabblers, and scrapers can access smaller areas. For all of these options the material left behind would need to be collected for treatment/disposal. Caution was expressed by the group regarding the ability to capture the dust or wastewater from such activities. This can often be a significant problem.

Figure 4 displays equipment that could be used to remove hard surfaces contaminated with radiation.

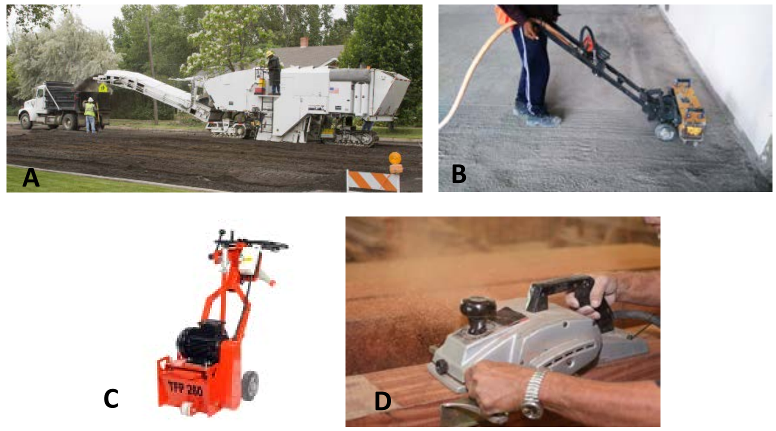


Figure 4. Surface Removal Equipment*:* A. Asphalt Removal Machine, http://www.appavers.co.uk/Hire/Planers/View-all-products.html; B. Floor Scabbler, http://trelawnyspt.com/products/scabblers/multi-headed-concrete-floor-scabblers-mhs5; C. Scarifier, http://trelawnyspt.com/products/scarifiers-planers/floor-scarifier-tfp-260-range; D. Handheld Scabbler, http://trelawnyspt.com/products/construction-scabblers/pneumatic-handheld-heavy-duty-construction-scabblers-sh1 (courtesy of Shutterstock).

We did not have sufficient time to collect responses to Scenarios 4-6 (washing many linear miles of pavement and collecting the washings, contaminated hard surfaces near a navigable waterway, and other thoughts not captured in the scenarios, respectively) from Workshop participants, but did receive responses from the UK collaborators (see Appendix A).

3.4 Training (Summary)

The Workshop discussion on the morning of March 17, 2017, focused on training. The workgroup participants agreed that it will be challenging to pull together the expertise and workforce in a major response, and that it be good to develop a training package. There will be limited Health Physicists to do monitoring, and finding good equipment operators is going to be a challenge. Just-in-time training will also be difficult as workers will be required to receive 40-hour Hazardous Waste Operations and Emergency Response training. It will be critical to identify the expertise and workforce that are required ahead of time. A National Council on Radiation Protection and Measurements report, *Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers* (NCRP 165), provides recommended levels of training for various emergency responders and would be a useful resource for planning.

Some observations about workforce development included mention that Japan's current training program is not extensive, due to number of workers required. Also, EPA contractors would have to go through a criminal background check, enhancing the reliability of the workforce but leading to a longer ramp-up time. The National Guard participates in annual chemical, biological, radiological, and nuclear training and would be a good workforce. They would be useful for response and logistics, but we would be pulling them from several other specialty skills (90% are part time and have civilian employers). These individuals have an obligation to the National Guard, but there will be certain circumstances where they cannot leave their civilian work. Furthermore, the military would be expensive and not a long-term solution. Contractors are less expensive and longer term. Additionally, some states will use Department of Corrections workers (California firefighting was mostly inmates).

3.5 Waste Management

Contaminated, solid waste will be generated during mitigation and decontamination operations over a wide area from businesses and residences in varying sizes and container types. Solid, radioactive waste should be collected for staging and disposal. What types of municipal and commercial equipment can be used to stabilize, contain, store, and transport the radioactive solid waste generated during these operations? Examples include use of municipal waste garbage trucks and current routes to pick up garbage associated with small-scale (local) operations, using existing software and procedures developed for the transport of radioactive material to identify preferred routes, etc. The scenarios under Waste Management are described in Table 4.

Table 4. Description of Waste Management Scenarios

Support Goal:	**Waste Management**
	Scenario Description
Scenario 1	We suspect that radioactively contaminated material will be generated in residences as a result of personnel and self-help decontamination practices. How would the individual waste receptacles generated by residences be collected to avoid an accumulation of radioactively contaminated materials within multi-family units or at the curbside? Does the equipment and method of collection differ for more sparsely distributed suburban areas as opposed to congested downtown residences?
Scenario 2	How would the answer to Scenario 1 differ if the radioactively contaminated material is being generated by local businesses as a result of self-help decontamination practices? How would the individual waste receptacles generated by local businesses be collected to avoid an accumulation of radioactively contaminated materials in multi-business units or at the curbside? Does the equipment and method of collection differ for more sparsely distributed suburban areas as opposed to congested downtown businesses?
Scenario 3	If the accumulated radioactively contaminated waste is being collected at staging locations (for example, parks and common grounds), what types of containers can be used to collect the waste receptacles and protect the public from transport of contaminated particles (for example, through resuspension of breached receptacles)?
Scenario 4	Do you have other thoughts or specific questions based on your experiences in your geographical area related to this topic?

Summary of Waste Management

Workshop discussions primary covered Scenario 1, the collection of waste receptacles generated by residents in order to avoid an accumulation of radioactively contaminated materials at the curbside. Most of what was discussed could be applied to Scenario 2 (collection of waste from small businesses) as well.

A significant topic of debate was the categorization of waste. One participant suggested that if we permit people to live in a contaminated area, then we are implicitly saying that there is no danger from the low levels of contamination. Therefore, any refuse or garbage generated will be considered normal municipal garbage and not radioactive waste and, so, should be treated as such (collected at the street, hauled, sorted, and disposed).

The State regulates waste within the borders. They have the authority and do not need permission from the Nuclear Regulatory Commission (NRC) or EPA, so we should not be considering the current methods for dealing with radioactive waste. The State may authorize use of a landfill, but it will be owned by a private company that may want certain requirements met. The bottom line is that we are going to have to work with the waste facilities.

Unless residents are evacuated, the waste will have to be collected. A non-evacuation area will likely have a continuous and very low level of contamination. Waste collection will most likely remain business as usual, but preparations will be needed to deal with the large amounts of waste, including soil, carpets, furniture, etc. If the EPA determines that cleanup needs to be done a certain way, the EPA will have contractors (not landowners) perform the work. However, there will always be individuals who do not hire contractors and attempt to perform the work without federal assistance.

Public perception and mistrust in city/state/federal agencies is going to be a major problem. Examples of the Ebola (2014) and Flint (2015) incidents were given. A very common problem identified in most federal exercises is that we continually have difficulties in establishing standard recommendations across political jurisdictions. It will be difficult to get one message out. People will do what they want to and may not follow waste collection rules.

We will need a plan for issues that may cause re-entrainment or re-aerosolization (e.g., guidance on how to dig up soil). Additionally, the hot spots for self-help remediation will need to be defined, and a process will need to be in place to handle these materials. An example was given of recent experience in Japan. After the Fukushima reactor accident, a Japanese Mayor gained trust by gathering health physicists to provide him guidance. Educating and sending a unified message to the people kept the community from evacuating and allowed for the village to recover sooner than others.

FEMA will be offering a new course, Radiological Operations Support Specialist (ROSS), which will help identify training and tools around the country. It was emphasized that education, training, and practice are essential.

Modeling was discussed as a way to determine what the approximate dose for garbage truck operators will be after being exposed to a continuous amount of garbage each day. If operators were to wear personal protective equipment, it would send the wrong message to the community. The general consensus was that garbage trucks would operate as normal; however, the State would handle regulations and be responsible for solutions to these problems.

The maintenance and decontamination of garbage trucks were briefly discussed. The overall consensus was that it makes sense to maintain/clean the truck. However, with equipment such as excavator buckets or wear items (brushes, excavator bucket edges, aprons), it may be more cost effective to dispose of rather than try to decontaminate them. The EPA Integrated Wash Aid Treatment for Emergency Reuse System (IWATERS) was mentioned as something relatively cheap that could be used to wash trucks.

We did not have sufficient time to collect responses to Scenarios 3 and 4 (types of satellite receptacles that can be used to collect waste at temporary staging locations and other thoughts not captured in the scenarios, respectively) from Workshop participants, but did receive responses from the UK collaborators (see Appendix A).

3.6 Containment of Water, Wastewater, and Other Wastes

Water will likely be used by first responders to extinguish fires that may be generated during a radioactive release. Water may also be used to reduce radiation levels to early responders and subsequent response teams. Ideally, the water could be collected and treated at the point of use. However, we may need to collect, divert, and store radioactively contaminated waters for proper treatment and disposal. What types of municipal and commercial equipment can be used to collect, contain, and transport liquid wastes and other wastes not identified in the Waste Management support goal. Examples include portable tanks and storage bladders, barges, tanker trucks, railroad tank cars, fixed tank farms such as at refineries, the storm sewer, and sewer water storage tunnels and reservoirs to facilitate collection of contaminated waters. The scenarios under Containment of Water, Wastewater, and Other Wastes are described in Table 4.

Table 4. Description of Containment of Water, Wastewater, and Other Wastes Scenarios

Support Goal:	**Containment of Water, Wastewater, and Other Wastes**
	Scenario Description
Scenario 1	What types of barriers (for example, sandbags and berms) are available to collect water that is generated during its large-scale use (hundreds of thousands to millions of gallons) over a small urban footprint (for example, 1 square city block)?
Scenario 2	What types of barriers (for example, sandbags and berms) are available to collect water that is generated during its large-scale use (millions of gallons) over a large urban footprint (for example, 10 square city blocks)?
Scenario 3	Do the answers to Scenario 1 and 2 differ if the water is used to wash down vertical as opposed to horizontal surfaces?
Scenario 4	If the water is collected at the point of use, what containers/vessels/facilities are available to store the water generated in Scenarios 1-3 until it can be processed or transported?
Scenario 5	If the water penetrates the sewer system and can be diverted at a downstream collection site (for example, just prior to entering the water reclamation district or wastewater treatment plant), what containers/vessels/facilities are available to store the water until it can be processed or transported?
Scenario 6	If we wish to avoid the sewer system, what other methods of diverting water are available to collect water at a central location?
Scenario 7	Are there existing trench, dam, retention ponds, community reservoirs, etc., available to collect water, and are there paths for directing the wash water from its point of use to these existing collection systems?
Scenario 8	Do you have other thoughts or specific questions based on your experiences in your geographical area related to this topic?

Summary of Containment of Water, Wastewater, and Other Wastes

It was emphasized throughout the conversations that in emergency incidents such as an improvised nuclear device or nuclear power plant response, the fire department is going to do what they need to do to save lives and control fires. They will try to isolate and divert the wastewater, but the reality is most of the water will initially go into the sewer system. However, for the cleanup, it will be necessary to work with the sewer authority to determine the best ways to control the movement of water.

Scenarios 1 and 2 focused on identifying the types of barriers that are available to collect water that is generated during large-scale use over a small or large urban footprint. The suggested solutions for handling the collection of water included:

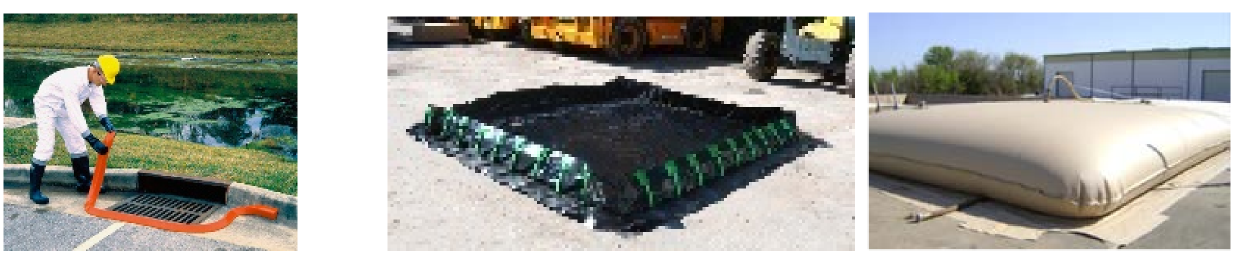
- Typical berms and bunds could minimize the impact of spillages.
- Drains could be protected/covered to prevent run-off of water to municipal drainage systems.
- Emergency collapsible berms systems (IWATERS) that are used around the world for floods and U.S. troops could be used instead of sands bags.

Large-scale incidents may require the use of the natural topography and storm sewer systems to collect or divert water. It will be necessary to understand the treatment facility's shutdown and bypass capabilities.

Scenarios 4 and 5 focused on the containers/vessels that are available to store the water generated or diverted until it can be processed or transported. The possible diversion and storage solutions included:

- Berms/bunding/plastic sheeting combined with sandbags or gravel filled bags could be used to contain water, which could then be pumped into tankers for transport (would not control large quantities of contaminated water).
- The water district may be able to divert and use bladders to plug the system to hold water until later.
- The construction of temporary "lagoons" could store water diverted from the drainage system.
- A piping system could carry contained water to a reservoir for storage or treatment.
- Large tanks and barges could be used.

Figure 5 displays some options for water dispersion and containment.



A **B** **C**

Figure 5. Water Diversion and Storage Containers. A. Flexible Temporary Berms, permission granted 1/29/18 from Ultratech (M. Cruz); B. Thin-Walled Bunds, permission granted 1/29/18 from Ultratech (M. Cruz), C. Flexible Tanks, permission granted by Controller ModuTank Inc. (H. Carren).

For scenario 3, collection from vertical surfaces will be difficult. It will be necessary to use the topography and find the low spot to contain water. The wash-down needs to be a top-down process where the soil is removed afterwards. If critical infrastructure does not follow topography, then the use of berms or basins will be likely. There will be an effort made to get critical infrastructures clean enough to open for operations, and it may have to be cleaned multiple times. Additionally, the personnel may have to receive radiation training. Vacuum trucks may be used to remove any contained water from vertical wash-downs.

It was clear from our discussions that we need to obtain participation from the water authorities and the sewer districts in order to obtain an accurate assessment of the capabilities for collecting, diverting, and storing water discussed in this support goal.

We did not have sufficient time to collect responses to Scenarios 6-8 from Workshop participants, but did receive responses from the UK collaborators (see Appendix A).

4. Feedback Form Summary

The organizers distributed Participant Feedback Forms at the conclusion of the Workshop. A total of eight of those present turned in completed forms. Participant job responsibilities were heavily weighted toward the survey and monitoring expertise and ground level assessment. We did not have anyone with positions at critical infrastructures (water treatment, transportation, tunnels and bridges, etc.) or sewers and sanitation, communications, National Guard, county level response teams, or industrial environmental contractors. In short, the participants felt that the scope was too large to be addressed in one workshop. The consensus was that we need to reduce the scope of scenarios covered during Workshops and work in smaller teams with more focused expertise such as subgroups for water, solid waste, survey and monitoring, etc. Then, these sub-groups could discuss recovery options, techniques, and equipment, and bring these vetted ideas to the larger group.

5. Wrap Up

The purpose of this first Workshop was to introduce a broad swath of experts from within Illinois and federal response personnel to gain a first-order understanding of the approaches and concerns within each of the support goals. From this, we expected to better understand how to plan future Workshops that can be more effective in soliciting responses and moving closer toward arriving at a consensus on technologies that might be suitable for a timely recovery effort. This document serves the purpose of providing a summary on which to build and focus future effort.

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Appendix A: Raw Notes of Responses to the Scenarios

Scenario Description: Survey and Monitoring	Scenario Response (Please provide specific ways in which you would respond to the scenario and what types of equipment you would require. Please use NIMS typing if it is available and you are familiar with the FEMA NIMS system.) Note: Below includes returned responses and responses captured during the Workshop.
Scenario 1: We wish to measure on a regular basis the contamination levels in areas initially affected by contamination (that is, fallout deposits of radioactive material) in terms of external dose at the street level (that is, the radiation levels at the street from external gamma and beta radiations). What equipment can be used to provide such measurements, and what tools do we have to develop maps of contamination with this data?	One example could be ion chambers with and without closed window on a postal vehicle (live time system). Do we want to have grab samples such as vehicles that move around on some regular time period? Most likely need to consider both CPM vs. DPM measurements--not sure how cleanup level will be determined. FEMA/EPA/DOE has Rad Responder, which is web-based tool with apps on phones, laptops, etc. and gathers rad info that is uploaded to a central database that designated users can view. Assortment of detectors can feed into rad responder. If wide area response, going to have National Framework Response (NRF) where FRMAC will be deployed. A lot of initial measurements will be performed by FRMAC, and there will be a long-term environmental data management program, and they will look at how to track contamination over time. Have equipment to track and tie into GPS and data management portions. EPA has data management tools used for Flint, etc. There are tools already in place that can be used for assessment, etc. Maybe we have the assets to understand the data because of the complexity of the info from these detection devices. DOD might need assets that are closer in proximity and may not be able to bring in the experts on rad detection - they must bring in non-experts using organic assets. It was noted that DOD force protection, which is distinct from any other type of environmental monitoring which is focused on decision making evacuation/relocating and protecting the public. There is a need for continuous monitoring in places that may not have initial characterization – or maybe had been cleaned initially but need to optimize the ways to monitor areas over a long period of time using routes that are already in place, air monitoring, etc. Get those plans ahead of time. Sanitation Trucks/Snow Plow in NYC –an app gives info on location of vehicles. What about the assumption that the normal route schedules for such vehicles is not occurring because people have evacuated? What is situation (radiological dispersal or improvised nuclear device) that may isolate the area, e.g., different areas of contamination may require a layer approach or equipment might differ depending on area. National Guard Civil Support Team or State of Illinois has a crew of vehicles with identification detectors. Will require a trained scanning campaign, rather ad hoc. Feedback from the UK included: • GPS-integrated detection • A 3D mapping gamma camera • Vehicle mounted large aperture • EPDs (Electronic Personal Dosimeters; • TLDs (thermo-luminescent dosimeter) • Manned, detailed measurement surveys

	• Small agile vehicle capable of covering areas required quickly.
	  o Detector(s) that provide a dose rate with beta/gamma differentiation.
	  o Automatic data logging of dose rates, location, date/time and instrument.
	• Smart phones (10 μSv/hr)

Scenario 2: We wish to measure on a regular basis the contamination levels in areas initially affected by contamination (that is, fallout deposits of radioactive material) in terms of external dose within residences and businesses (that is, the radiation levels within the homes, apartments, or business offices from external gamma and beta radiations). What equipment can be used to provide such measurements, and what tools do we have to develop maps of contamination with this data?	Some responses above apply here as well. TLD on bus routes. Put TLD on cat before going out, pigeons, etc. Enough TLDs could build up a picture of contamination in area. Ultimately, want confidence in measurements, so can have a high-fidelity measurement device in a few of them, but don't have representativeness, a lot of low fidelity, don't have high fidelity, but do have representativeness which may be quantified – could do a cost-benefit analysis to look at different options. Perhaps lower fidelity and higher standard validation techniques can be used together (such as the use of smart phones or personal detection devices). Web site that allows user to input qualitative data on rad levels. Instadose by MIRION Technologies has a USB dosimeter ($25). Great for shift work, but cheap enough to deploy to many types of vehicles, animals, and structures and could be given to people to track their own dose and feed it to a central database. Also, there are pager-type devices that have Bluetooth capability that will automatically connect to rad responder. Workers could send data through pager while they are working. It was noted that we are at the point of response where we are documenting low levels, not in hot spots that would change relocation. After Japan, public purchased own detectors and reported findings through social media and then eventually someone mapped contaminated areas. The government used it as a tool/opportunity to validate contamination in areas. Need to be prepared for this type of public response. Chicago Fire Department (FD) capabilities: Everyone has a PRD, CO meters on all crews (in and out of houses/structures), and log dose every day as part of procedure. Some people won't leave, so crowdsourcing them to wear a dosimeter may be a good idea. Car oil filters – data that you could gather- same sort of collection efficiency- is there a way to correlate the rad in filter to miles driven and dose (or air filter)? Some research may be helpful. Feedback from the UK not already captured above included: • Regular monitoring campaigns during periods that the buildings are not in use • Tacky mats
Scenario 3: In the areas affected by contamination, we wish to measure on a regular basis the resuspended contamination levels at the street level (that is, the contamination attached to airborne particles	Region 5 has been working on indoor mapping techniques. Have instruments that can use Light Detection And Ranging (LIDAR) laser scanning so we can see and map out interiors and have radiation equipment attached. With the Leica total station land surveying systems Region 5 currently has, and with mobile mapping systems like the Leica Pegasus, we can collect geo-spatial data with GPS-style coordinates, as if we are using GPS systems indoors. And have tools developed for lead-contaminated homes. Tablet applications tied into ArcGIS. Enable people to take X-ray fluorescence (XRF). Developing ways for doing XRF measurements, then collecting indoors and doing data management collection and data management processes. Could be adapted for rad.

that are suspended in the air as a result of vehicle travel, pedestrian travel, or wind). What equipment can be used to provide such measurements, and what tools do we have to develop maps of contamination with this data?	Airnow.gov tells you air quality by zip code. Could we leverage this network to provide rad levels? EPA's RadNet system (https://www.epa.gov/radnet) monitors the nation's air, precipitation, and drinking water for radiation, but there will be a bottleneck with the labs trying to process samples. Canberra has a system called ECAM. DOE and FRMAC have about 25 to support NASA missions. It is a real-time air monitor with a filter. It does some form of alpha spectrometry so can somewhat knock out effects of radon that can interfere with contaminant identification. BioWatch (https://www.dhs.gov/biowatch-program) filters could hand these over for rad analyzing as well. Feedback from the UK not already captured above included: • Base stations with air samplers • Wind-sock filters or items such as "tachyshades" • HVAC systems can have filters • Air samplers available as commercial-off-the-shelf (COTS) • Industry air monitors • Vehicles such as bus or garbage collectors with regular routes, which could have filters analyzed (mentioned in scenario 1) • Personal air samplers (PASs), which collect airborne contamination in the immediate vicinity (mentioned in scenario 2)
Scenario 4: We expect tracking of contamination from the initial deposit area to other areas via vehicle and personnel transport. What equipment and methods can be used to identify these contaminated egress routes? For instance, can vehicles originating from a contaminated zone be tracked using existing highway cameras?	Tacky mats for vehicles were briefly mentioned. Feedback from the UK not already captured above included: • Monitoring and clean down, where appropriate, of vehicles. Vehicles exiting the contaminated areas would require a wash down. • Portals on the exit from the contaminated zone. • Airborne-wide area monitoring, such as helicopter or UAV mounted detectors.
Scenario 5: How would the above equipment and methods differ if the contamination occurred at a	We need to keep this open even in the evacuated zone. EPA is planning that these areas are where we will be. Facilities with rad materials already (hospital) monitoring capabilities already in place, so we need to use these. Other industries (universities) have ongoing monitoring activities. Partner with them to access their data and assets. So, essentially convert rad facility personnel into occupational workers to help monitor the exposures, etc.

critical infrastructure such as a hospital, wastewater reclamation facility or drinking water treatment plant, airport, or communications centers (for example)?	Feedback from the UK not already captured above included: • Portal monitors or hand-held monitoring equipment. • Prioritization of the infrastructure.
Scenario 6: Other ideas related to monitoring and procedures: i. Can we use traffic cams to evaluate the most used thoroughfares? ii. Can we use traffic cams/red light cams to track individual vehicles for follow-up survey for those most severely contaminated? iii. Can resulting dose maps be used to determine the best evacuation route to reduce the amount for exposure and facilitate the tracking of radioactive contamination?	*Workshop participants were instructed to provide input later*
Scenario 7: Do you have other thoughts or specific questions based on your experiences in your geographical area related to this topic?	*Workshop participants were instructed to provide input later*

Support Goal Training: Wide-area radiological contamination incidents are rare, and a response to such an incident will require tremendous human assets. We learned from the cleanup efforts in Japan that many thousands of individuals each day are engaged in clean-up activities. What are your thoughts and recommendations on availability of trained human assets and training of additional assets that will likely be needed in order to accomplish the scenarios under this goal? (Note: We realize that training will be a significant effort and an additional limiting factor in any response scenario. Further, it may need to be addressed more thoroughly in the future, but we would like input to help guide how we should continue toward developing training guidance.)	*Workshop participants were instructed to provide input later* Feedback from the UK included: There are shortages of monitoring equipment and trained personnel for survey and monitoring. We would be interested to know if this view is valid, and whether this was an issue in Fukushima? The most experienced existing monitoring personnel would be best deployed on: i) high hazard/high value activities, e.g., evidence recovery; ii) containment activities to prevent the situation degrading further, e.g., contamination monitoring at defined boundaries between areas; iii) training of additional resources to provide operational monitoring within the remediation zones; and iv) clearance monitoring for priority areas which need to be returned to operation quickly. It would be beneficial to try and establish some monitoring stations where automated monitoring systems (such as hand and foot monitors) can be used by less trained staff with little risk. These types of station already exist at Chernobyl. Nuvia currently offers NVQ Levels 2/3 for Radiation Protection and Nuclear Decommissioning, and sections of a typical NVQ syllabus could be extracted to meet the requirements of different roles. A general approach to grade the level of training required could be considered, such as: Level 1- Low risk activities (e.g., operating a monitoring vehicle whilst remaining in a sealed cab at all times). Personnel would have basic understanding of radiological risk and understand the dress, undress, and monitoring procedures for their role. Level 2 - Lower risk activities - such as monitoring items and personnel between relatively clean areas (such as from sealed vehicle cabs at designated clean areas). Level 3 - These would be people with baseline training as above and some experience, who have demonstrated competence in their technical field. Level 4 - These would be people who have more experience and a broader knowledge of the operations and required controls. Level 5 - These are fully competent and experienced personnel who could lead and mentor lower level personnel.

Scenario Description: Mitigation of Received Dose to First Responders	Scenario Response (Please provide specific ways in which you would respond to the scenario and what types of equipment you would require. Please use NIMS typing if it is available and you are familiar with the FEMA NIMS system.) Note: Below includes returned responses and responses captured during the Workshop.
Scenario 1: We have identified that airborne contamination is a significant source of radiation dose to unprotected people. Given that the contamination after settling is primarily found on horizontal surfaces (e.g., streets, walkways, parking lots, urban green spaces), reducing the potential for resuspension is a potentially important goal. Through prior research, we have identified materials such as gravel, mulch, and sand as effective means of reducing resuspension if the material can be laid down over the contaminated surface. How would such material be distributed over an area of several linear blocks? How would such material be distributed over an area of several square miles?	Northern lights exercise working with Minnesota used brine solution (used to prevent icing). The brine solution is tacky and will wash away, and one does not have to worry about cleaning up solid waste (such as gravel) later. Rural areas have trucks to spray herbicides and may use similar equipment that incorporates chelators or other agents (to grab ahold of isotopes). Salt was found to be effective. Salt water is easy to access, and removal will be better than just rain water alone. Dust control agents (tackying agents are added) can be used for mountain top removal, etc. Oils may be added to the tackying solutions in mining sites. These agents are readily available and cheap. Also, HEPA street cleaners may be useful before first rain to reduce the initial contamination - use little or no water just to reduce the dose. Street sweepers should use EPA-rated sweeper based on emissions out of the tap. Old studies on old sweepers showed they are not good when it comes to picking up dust and better with gravel. Have not seen any recent studies focused on this. EPA/DHS tested salt distributions to determine suppression of resuspension and shielding. Salt is not good at shielding but did provide some suppression. EPA tested mine site fixatives, which proved to be good and widely available. Also, tested was forest fire orange agent (fire retardant), which is not good for radiation protection but provides resuspension protection, and will have an environmental impact later after release to urban area. Concerns are how to apply to the highway? How often do we apply? How much waste will be generated? Where are radionuclides going to end up, so we can target for hot spot cleanup? All this is worth testing. Fukushima had resuspension problem for 6 months out. Was this because they were doing so much decommissioning? In Japan, March–June is dry, after June a lot of humid air and rain. In the United States it might be dry - can't wait for rain in U.S. We need to respond to problem. Have to clean up after contamination is treated and deal with the waste. Military has been using dust suppression technologies and equipment for a long time, especially for desert operations. The Air Force would be good to check with for suppressants and application technologies. Feedback from the UK included: • Dumper trucks • Helicopter/firefighting aircraft dumpers. Similarly, a foam/fixative could be spread by firefighting aircraft or crop duster type aircraft.

	- Salt spreaders - Drop spreaders - Chip spreaders - Gorilla-Snot® (https://www.soilworks.com/products-and-services/gorilla-snot.aspx), Durasoil®, and Soiltac®, which are "eco-safe, biodegradable, liquid copolymer used to provide erosion control and dust suppression." These were used by the UK in the recent past. - Rain frequency must be kept in mind (e.g., precipitation occurs every 3 days on average for Chicago and New York)
Scenario 2: We have identified that airborne contamination is a significant source of radiation dose to unprotected people. Given that the contamination after settling is primarily found on horizontal surfaces (e.g., streets, walkways, parking lots, and urban green spaces), reducing the potential for resuspension is a potentially important goal. Through prior research and experience, we have identified that washing the surfaces with fresh water is effective in removing contaminated particles from surfaces, thereby reducing the dose in the immediate area. How would fresh water be distributed over an area of several linear blocks? How would fresh water be distributed over an area of several square miles? How do the methods change if we need to distribute the water over vertical surfaces such as the facades of buildings?	Dust suppression also incorporates seeds to help promote grass growth, which will knock down suspension long term. For pavement, companies could spray parking lots in a day. It was noted that if it is a heavy contamination, probably going to do a knock-down with helicopter before responding. Water may not be effective for removing the particulate but could remove/suppress particulate that could re-aerosolize. Just trying to get road open and reduce suspension, you can let run off go to the ditch, because you are going to have to clean up anyway. Not ideal, but if you are trying to reduce resuspension this may be effective. In a heavily urban environment, can't just let waste water enter the sewage treatment plant and kill all the bacteria. It's going to enter no matter what - a portion will always be going into it. Older cities have combined sewer systems so what goes into the ditch goes into sewer system; in newer cities these are separate. All Liberty Rad Exercise wastewater would have gone into a combined sewer system. High dose rates, like a dirty bomb epicenter, may want to use imaging devices, such as a thermal camera standoff system where you can get 2D maps of contamination. Combined sewer systems have grit removals at front end, and possibly insert some clay or other sorbent and the downstream grit removal/collector can filter out the contamination. Use sewer as collection point when washing down streets (using plugs to divert and control water flow). Chicago uses containment bladders and vacuum trucks to suck out solids. For waste water and storm management operated by locals, need communication with Water Environment Research Foundation (WERF) types on how to treat water. Japan was trying to find an effective way to knock down the radiation levels. They identified hot spots as sludge and debris, and first thing they collected sludge and debris from storm water system, dried it and burned it. To clean waterways, they disturbed the sediment in the waterway and then allowed for settling and the rad could be filtered/removed. Vacuum trucks are used almost everywhere there.

	In Chicago, they use vacuum truck, sewer rods if necessary, then insert a polymer sleeve that expands and lines the inside of the sewer bed. This is a way to seal the sewer itself and may be a remediation option after the fact. Could let storm water go into basins, then when done cleaning, remove six inches of soil out of basin. There is a need for high horsepower pumps. In Japan accident, Cs was chemically bound to surface, so they used a more aggressive method - 50,000 psi high pressure washer on surfaces - to remove Cs. Feedback from the UK included: • use of existing hoses (e.g., firefighting hoses) and personnel • firefighting aircraft/helicopters to dump water over large areas; similarly crop duster type aircraft • portable water pumps • water trailers
Scenario 3: We have identified that airborne contamination is a significant source of radiation dose to unprotected people. Given that the contamination after settling is primarily found on horizontal surfaces (e.g., streets, walkways, parking lots, and urban green spaces), reducing the potential for resuspension is a potentially important goal. Through prior research and experience, we have identified that washing the surfaces with water containing salt (for example, seawater or salty water from water softener units) is effective in removing contaminated particles and fixed contamination from surfaces, thereby reducing the dose in the immediate area. How would we generate the salt water and distribute it over an area of several linear blocks? How would we generate the salt water and distribute it over an area of several	Need cost analyses for bringing in seawater vs. mixing your own. Construction site equipment could be used to spray roads. Could spread salt in solid form and then let nature/weathering turn it into solution. [Nano] bubbles could be used to promote removal of rad without need for higher volumes of water. UK has done work with it. The Japanese may have tested it. Need a way to deal with regions that have limited water sources. Sensitivity is needed around laws and regulations for dumping or diverting waste water into lake or ocean systems crossing different countries, for instance, or to downstream cities not in affected areas that draw the water from the waterway for drinking. Salts affecting the fertility of the soils (UK decided in one decontamination operation to preserve fertility) and found that when area kept dry, they had no negative effect. Spraying saline on soil was going to kill the vegetation and, therefore, produce more dust from barren soil. Maybe initially we cannot stop the runoff of water but later we have to collect, store, and treat.

square miles? How do the methods change if we need to distribute the salt water over vertical surfaces such as the facades of buildings?	
Scenario 4: How would our proposed method of addressing Scenarios 1-3 change if the contaminated area were located sufficiently close to the ocean coast line or other navigable waterway such that maritime equipment and methods can be used?	Feedback from the UK included: • Existing water-borne fire fighting vehicles • Municipal/commercial water craft • Cruise ships and container ships for accommodation/offices/secure storage space for clean-up teams • Use of wetted sand to control dust
Scenario 5: We have identified that airborne contamination is a significant source of radiation dose to unprotected people. Given that the contamination after settling is primarily found on horizontal surfaces (e.g., streets, walkways, parking lots, and urban green spaces), reducing the potential for resuspension is a potentially important goal. Through prior research and experience, we have identified that applying a layer of sprayable polymer coating with a consistency of wet paint (for example, outdoor paints and epoxies such as those designed for roadways or other paved surfaces) to the surfaces is effective in tying down contaminated particles. How would we distribute this polymer coating material over an area of several linear blocks? How would we distribute it over an area of several square miles? How do the methods change if we need to distribute the sprayable coating over vertical surfaces such as the facades of buildings?	Feedback from the UK included: • For dispersal at street level, man-portable spray guns • Man-portable spray guns in tandem with window-cleaning rigs or vehicles such as cherry-pickers • Tankers and hoses, which could be used for dispersal • No significant complications with spraying over vertical surfaces other than access of man-portable equipment • Conventional paint • Highway paint

Scenario 6: How would the above equipment and methods in Scenario 1-3 and 5 differ if the contamination occurred at critical infrastructures such as a hospital, water reclamation facility, or drinking water plant, airport, or communications centers (for example)?	Feedback from the UK included: • Greater protection of the buildings may be necessary with particular care given to the prevention of water ingress into the buildings. • Critical infrastructure like drinking water and hospitals can be prioritized. • Hospitals might be inherently easily decontaminated because of hard surfaces. • UK has looked at airport decontamination in past.
Scenario 7: We have identified that airborne contamination is a significant source of radiation dose to unprotected people. Given that the contamination after settling is primarily found on horizontal surfaces (e.g., streets, walkways, parking lots, and urban green spaces), reducing the potential for resuspension is a potentially important goal. An area of concern is covered in contaminated debris and loose particles. In some areas, the debris is substantial and can be removed by bulldozer-type equipment. In other areas, the debris is such that it can be swept and vacuumed. How would you approach the problem?	Removal of grass. Sod cutting machines will work better on flat surfaces, not good for irregular surfaces. The 14-inch disc on power washers with nylon brushes that have spinning washers uses much less water, stays contained, and is very effective. Debris removal is a concern due to dust (even when wet). HEPA vacuum needed on dry debris removal machines to suppress dust. Also, could implement a misting unit first before vacuum. Large-scale vacuum units (ORNL tested?) exist in nuclear industry. HEPA vacuums in London (Litvinenko- polonium) did not work well on carpet and furnishing. Were more effective to cut out carpet, bedding, etc. Old data showed vacuum cleaners not effective in removing small particles. EPA did more recent tests showing ineffective on carpet, but dry particles even in small range were good (report in clearance office). Need to consider the different regions of U.S. when suggesting ideas - wetting things in Las Vegas or Phoenix will not work the way it would in more humid parts of country. Feedback from the UK included: • Dampen down affected areas to reduce the generation of dust. • Start by bulldozing through the area to gather larger chunks into discrete piles. • Smaller material could then be collected by either man-controlled HEPA vacuums, for example, or through use of municipal vehicles such as road sweepers. • Portable containment tents could be used. • Airborne hazards could be controlled using misting technology ranging from cheap misting hoses (for use in gardens) to industrial misting systems set up over larger areas.
Scenario 8: Regardless of scenario, how would the above equipment and methods differ if the contamination occurred along egress routes that are needed to transport people away from the affected area (for example, major highways)?	*Workshop participants were instructed to provide input later.* Feedback from the UK included: • Street vacuum/sweeper vehicles would be a valuable technique. • Water spraying will only move activity to drainage near the roads. • Pressure washing would be a key technique. • Following pressure washing, paint or other durable surface coatings could be used.

Scenario 9: Do you have other thoughts or specific questions based on your experiences in your geographical area related to this topic?	*Workshop participants were instructed to provide input later.* Feedback from the UK included: • Washing down surfaces, with whatever agent, generates very significant amounts of secondary waste in the form of contaminated liquids.
Support Goal Training: Wide-area radiological contamination incidents are rare, and a response to such an incident will require tremendous human assets. We learned from the cleanup efforts in Japan that many thousands of individuals each day are engaged in clean-up activities. What are your thoughts and recommendations on availability of trained human assets and training of additional assets that will likely be needed in order to accomplish the scenarios under this goal? (Note: We realize that training will be a significant effort and an additional limiting factor in any response scenario. Further, it may need to be addressed more thoroughly in the future, but we would like input to help guide how we should continue toward developing training guidance.)	*Workshop participants were instructed to provide input later*

Scenario Description: Decontamination (Gross and Final)	Scenario Response (Please provide specific ways in which you would respond to the scenario and what types of equipment you would require. Please use NIMS typing if it is available and you are familiar with the FEMA NIMS system.) Note: Below includes returned responses and responses captured during the Workshop.
Scenario 1: EPA studies identified that soil was a major source of contaminated material in decontamination effort in an urban environment. Prior research and experience suggest that by removing less than 5 cm (2 in.) of soil, nearly all the contamination can be removed. What equipment would be useful in removing a very shallow depth of soil from large urban green spaces such as playgrounds and open grass fields?	A good operator can remove 3-4 inches well using grade-all/excavator with a flat blade over the teeth. Key is not mixing it. Sod removal tools work well in very flat terrain like typical subdivision. Tree roots disturb the flatness. Even hand digging can be effective on a small lot. Is it more cost effective to cover with soil or rock rather than remove? Then, come back at a later time to clean. Problem with removal is: where are you going to get the backfill (sources will be limited in large area)? If you do not cover, you will face drainage problems. Trucks/existing assets can be fitted with scrapers. Potentially, there are types of equipment in agriculture that could be modified. Some areas may not want to remove top soil. In Japan, there are three choices for farmers: 1. remove top layer of soil, 2. turn over soil, and 3. apply chemical treatment- applying an inhibitor (potassium chloride) to inhibit rice uptake. Farmers preferred top layer removal, but problem was the removal of nutrients. With the inhibitor, products were fine, but farmers were exposed. Soil turnover turned out to be the best – had to treat with more nutrients, but not as much as for soil removal, and radiation reduction was good. In Russia, Chernobyl added ion exchange material into soil to fix the Cs in soil, performed deep plowing (3 ft), and chose crops judiciously. Chicago beaches have sand-sifting machines. These could be modified since they remove top layer and then sift top layers and lay them back down. Maybe something that can bind with the Cs before laying soil back down could be added. In the UK during plutonium particulate removal work, equipment was decontaminated except for scrapers and buckets and went into commercial use. Feedback from the UK included: • A range of standard construction equipment and municipal equipment could be used, e.g., JCB excavators, Kubota excavators, grass/turf cutters, snow ploughs, and hand tools (e.g., spades). • Vacuum tools (vacuum trucks) can be used to decontaminate dry loose soil/dirt covered lands.
Scenario 2: Same as Scenario 1 above, except that we wish to identify equipment that would be useful in removing a very	It was noted that some open landscapes are hard and cannot be easily removed/scraped. As a result, equipment would need to be brought into these confined spaces and entry ways such as yards and their gates.

shallow depth of soil from smaller, discontinuous plots of urban green spaces, such as front and back yards and garden areas.	Possible actions are pressure washing of rock gardens (done in Japan – could be appropriate for cities like Phoenix or Las Vegas) or wiping of rocks, and using hand scrapers to remove thin layer soil. This is very time consuming (420,000 houses). Can similar methods be used in larger plots? Homeowners are going to do cleanup if they do not have a choice. An EPA study is looking at outdoor cleaning approaches for homeowners. Going to have to have a wide area approach that focuses on reduction, not going to be a traditional approach – going to have to think outside the box. There is no simple answer. Timing is important. If you have broken communities, they are likely not coming back (after 6 months, people not likely to return). Will have to consider rebuilding vs. cleaning. Might be better to turn over to developers and let them redevelop – turn into green space. However, to start from scratch increases the amount of waste. Difficult decision to make. Where is the sweet spot – what amount of radiation people are people willing to tolerate? Don't see families of kids leaving Fukushima where contamination levels are low: they have learned to accept it. Feedback from the UK included: • As per Scenario 1 above, smaller manually operated devices may be more appropriate.
Scenario 3: Hard, horizontal surfaces such as roads, walkways, and parking lots can trap radioactive contamination. Prior studies and experience show that the contamination resides at or very near the surface of such hard materials (<1 cm or <0.5 in.). What equipment would be useful for removing contamination at the surface? What equipment would be useful in removing a very shallow depth of paving material? How does the choice of equipment and method change if many linear miles of surfaces need such treatment?	ANL is looking at conventional spraying to see how they can use in decontamination vs. high jet sprayers. UK did work years ago on horizontal surfaces – the type of patio cleaning high water jets with abrasive media with water capture and recycle. The problem was it could not contain the circulating water. For the nuclear industry test at Dounreay, sponge blasting was used (Pu cell). It permits addition of chemicals to promote removal of surface materials (sponge type pellets). It was very effective in reducing the dose rate. Used on different surfaces – delicate (paintings) and aggressive to remove thick layer of paint. Another possibility is dry ice blasting and other recoverable media ablation systems. Very specialized equipment is required. Bubble technology was mentioned but no details were mentioned. In any case, we need to consider how much surface you need to remove. Bluegrass Companies (Alabama) had concrete shavers in nuclear industry that use minimal water and are good at scaling up the layers that need to be removed. Could probably apply devices like this to roads, etc. Feedback from the UK included that the exact response would depend upon the surface; however, assuming tarmac, there are a number of options depending on the size of the area: 1) Asphalt remover could be used in conjunction with hand tools for smaller areas or harder to access areas. 2) Hand-held planers, scabblers, scrapers could be used for small- to medium-sized areas or harder-to-access areas.

	3) Vehicle mounted planers, JCB-style excavators or bulldozers could be used to strip off the surface of long linear areas. 4) Vehicle-mounted, very high-pressure jet systems could be used to remove surface layers in much the same way as a hydrolaser works; however, significant amounts of water would be required and a lot of waste water would be generated - this is not the recommended method. (Japan used specialized very high-pressure systems for roads.) 5) Chemicals could be used to remove concrete coatings. 6) Paving slabs could be used if contamination is large in between pavers. 7) Other specialty equipment exists such as Concrete Shaving by CoreCut. For all of these options the material left behind would need to be collected for treatment/disposal.
Scenario 4: As in Scenario 3 above, prior studies and experience show that the contamination on paved surfaces can be effectively reduced by washing these surfaces with water-based solutions. What type of equipment can be used to wash many linear miles of these paved surfaces and collect the washings?	*Workshop participants were instructed to provide input later* Feedback from the UK included: 1) Municipal vehicles and readily available commercial vehicles could be used for this scenario. 2) Road sweepers with attendant water tankers for re-filling with water could be used to cover large areas. 3) Fire trucks could be used; these carry large tanks for covering areas where fire hydrants are not accessible. 4) Aircraft, such as crop-duster style aircraft, could be used for airborne spraying or dumping of water over linear miles of such surfaces. They would not provide the same level of coverage; however, coverage should still be relatively good. 5) Larger aircraft/helicopters could be used, as they are for response to wildfires for example, to act as a "flush" after gross decontamination. For example, aircraft used for firefighting, e.g., a converted 747 (Supertanker), can dump up to 20,000 gallons of water. As discussed later, collection of generated wastewater would be an essential consideration. Berms and bunds, drain covers, etc., can be used to help direct and collect water. Where washing is not possible or appropriate, other options include: Manually lift and flip flagstones (over small areas) if required, and CO_2 blasting of flagstones (over small areas).
Scenario 5: How would our proposed method of addressing the scenarios above change if the contaminated area were located sufficiently close to the ocean coast line or other navigable waterway or river system such that maritime equipment and methods can be used?	*Workshop participants were instructed to provide input later* Feedback from the UK included: • If this were the case, then existing water-borne fire fighting vehicles could be utilized if they are available or can be brought in. • Standard personal/municipal/commercial watercraft can also be used with the addition of pumps and hoses to the craft. The easy addition of pumps to normal craft would allow for the drawing of water directly from the ocean/waterway and pumping of the water straight onto the buildings in question.

	• With regards to the use of airborne vehicles, the presence of waterways/ocean could significantly speed up the dispersal process and reduce costs as, with the use of suitable equipment, water could be scooped up directly from the water sources and then dispersed (e.g., by the use of "Bambi Buckets," aka helicopter or monsoon buckets).
Scenario 6: Do you have other thoughts or specific questions based on your experiences in your geographical area related to this topic?	*Workshop participants were instructed to provide input later* Feedback from the UK included: • A top-down approach could be used to clean building sides and roofs first, if needed, using water for large structures but with aerosol cross-contamination in mind. • It should be considered that not all contaminants are easily removed using water, and that the use of water, with its associated generation of significant volumes of secondary waste, may not be the best option in many situations. Collection of water washings is often very difficult despite best efforts being made. • The weather could play a major factor in determining where the activity goes. In addition, access restrictions due to abandoned vehicles could cause problems.
Support Goal Training: Wide-area radiological contamination incidents are rare, and a response to such an incident will require tremendous human assets. We learned from the cleanup efforts in Japan that many thousands of individuals each day are engaged in clean-up activities. What are your thoughts and recommendations on availability of trained human assets and training of additional assets that will likely be needed in order to accomplish the scenarios under this goal? (Note: We realize that training will be a significant effort and an additional limiting factor in any response scenario. Further, it may need to be addressed more thoroughly in the future, but we would like	*Workshop participants were instructed to provide input later* Feedback from the UK included: • Such decontamination responses require a unified effort with a central chain of command. This is essential to ensure safe decontamination of adjacent areas, etc., and to prevent re-contamination of previously decontaminated areas. • It is also essential that clear objectives are set, in as much as a defined end point, or "clean-down level" must be decided upon for each location/surface/etc. prior to the start of decontamination. Any remediation/decontamination would need to be legally defensible by the supervising authority. • Decontamination of small plots of land may be more cost effective and achievable if undertaken by landowners. Minimal training is required to use a shovel, although respiratory protection against resuspension of material and suitable waste disposal measures would clearly need to be considered as part of any training. • We have resources with nuclear site experience that are trained as riggers, fitters, heavy goods vehicle drivers, forklift operators, etc., but for a large scale incident, suitably-skilled and qualified personnel (SQEP) with radiological experience would be in short supply. Providing basic radiological training for specialist operators with no radiological experience is likely to be the most cost effective and timely option for ensuring SQEP workers are used on site. Teams would include trained Health Physicists/Monitors to ensure radiological safety of all staff on site. This is common practice on non-nuclear sites for remediation work.

input to help guide how we should continue toward developing training guidance.)	

Scenario Description: Waste Management	**Scenario Response (Please provide specific ways in which you would respond to the scenario and what types of equipment you would require. Please use NIMS typing if it is available and you are familiar with the FEMA NIMS system.) Note: Below includes returned responses and responses captured during the Workshop.**
Scenario 1: We suspect that radioactively contaminated material will be generated in residences as a result of personnel and self-help decontamination practices. How would the individual waste receptacles generated by residences be collected to avoid an accumulation of radioactively contaminated materials within multi-family units or at the curbside? Does the equipment and method of collection differ for more sparsely distributed suburban areas as opposed to congested downtown residences?	Need to understand DOT regulations for transport considering everything might be contaminated. What are the regulations for transport of radioactive materials within and outside a contaminated area? If it is within the contaminated area, does DOT regulate matters? If considered onsite, then the On-Scene Coordinators (OSCs) have latitude on how transport is handled. For sites designated by Comprehensive Environmental Response, Compensation, and Liability Act, the OSCs can waive certain administration requirements. The State regulates waste within the borders. Unless you evacuate, you have to collect the waste and have to be prepared to deal with large amounts of waste, soil, carpets, furniture. The State has the authority to regulate – does not need permission from NRC or EPA. What kind of equipment will help? Two truck scheme: Truck 1 picks up bins, detects levels, and hauls them away if below cut-off criteria. Second truck collects those rejected by first truck. Rad-dependent approach to collection and disposal. Treat it all as garbage, just more of it? It will remain business as usual. Workers are going to recycle and put garbage in bins/truck the same. You can't expect them to do special things to divide waste, etc. It will not happen. You need to deal with waste OR you evacuate. Workers are not necessarily going to follow all the disposal rules. There could be two phases: Early on, known contamination, soil, etc., is handled. Thereafter, going to have a continuous very low level of activity and might have a different allowance per collection. Our instrumentation is going to monitor for health and safety not waste. Will not be looking into how to monitor, but looking at places that are going to take the waste. Make decisions. All the hot stuff from the incident will be in the evacuated zone. Don't need to worry about hot showing up. If you move contaminated garbage off the street, you may take public pressure off. Not many lessons learned from Japan. All going to be treated as rad waste and treated by method of incineration. Waste is accumulated and sorted out. Equipment would include garbage trucks, operating as normal. Do we need garbage men in personal protective equipment? That is not going to send the correct message because we told the people they are safe. But they are going to be exposed to a large amount of garbage all day. Should model what the dose going to be for the driver. State is primary regulator, so they will be responsible for solutions for this problem.

	Concentrating garbage into trucks and collection facilities produces what dose? Going to be difficult to re-concentrate the stuff. A concentration is not likely. Think you are going to do the same thing you always do. There may be concentrations that are higher (soil gutters, etc.), but would we define it as a hot spot? Will need a plan for when they dig up soil, etc., because these are issues for re-entrainment and re-aerosolization - different than garbage. Provide bags they can put waste in. Transport in suburb (Raleigh) may spread contamination out further to surrounding counties. So many different services/paths for those outside city limits. May have some areas refuse to take waste. It will be a nightmare trying to prove that was is not radioactive. New York does not allow radioactively-contaminated waste in their landfills, but the state of New York does have another landfill. State determines what is allowed in landfill. Class C RCRA waste landfill allows certain types of contamination at a certain level (lead, PVC). Class D waste is not allowed to have federally classified waste such as municipal landfill waste. After incident, it may be a waste class issue, but it is the state's responsibility to designate the waste classification. May authorize use of landfill, but still owned by a private company that may want certain requirements met. We have to get away from thinking about our commercial methods for dealing with radioactive waste now. Bottom line is we are going to have to work with the waste facilities. An assessment needs to be done based on how you spend your time. Let us work on reducing levels and give them advice on what to do (only spend X hours in the garden, etc.). Do we see the need to maintain the equipment, dump truck, etc., for decontamination? Class C sites have wash down areas for vehicles and equipment. Makes sense to maintain/clean the truck. At Maralinga, they did not want the plow to break down in the field, so it was maintained daily. The excavator bucket was cheaper to write off rather than try to decontaminate. City of Chicago maintains their trucks, but does not wash trucks every day. The EPA IWATERS is relatively cheap and could wash trucks. Advantage of vehicles is their hard non-porous surfaces. If we have evacuated and non-evacuated zones across the street from each other, then restricting transport of waste for pickup becomes a "non-issue." There will be crossing zones. Superfund sites are easy to control access with a fenced perimeter and does not cost a lot of money. We may not have such control in an urban setting. Workers just need to pick up waste and take it to a facility that

	handles decontamination waste. This is what they do at Class C sites. But when they do self-help cleanup of soil, gutters, and areas that may have higher contamination, there are differences, and a process must be in place to handle these materials. For daily commerce, you are either in evacuation or non-evacuation areas. In an evacuated area, we have control; for non-evacuated areas, we have to advise. Are there any NCRP-written documents that contain this information? What container will be used for waste? In non-evacuated zone, if we are saying it is safe to walk around, then just put the garbage out for pickup like normal. When incident happens, EPA would be having contractors do cleanup in a certain way. Can't control public, but EPA may say do not do this or that. Gets to a situation where we think we need to do something a certain way, will tell contractors (not land owners) to do this way. But there will always be folks who take things in their own hands. Hard to believe people will listen. They are going to put everything out even if they do not meet the specs of the waste collector, and the waste may just stay there. What do we do? Same thing we do now. Citations from county government for not obeying the rules, or regulatory agency takes it upon themselves to do something. It will be an overwhelming situation. What agency is going to be in charge of distributing self-help guidance because no one wants to take ownership, especially over multiple jurisdictions? A very common problem identified in most federal exercises is that we continually have difficulties in establishing standard recommendations across political jurisdictions. Robocall communications can be put out there. It was mentioned that there is so much mistrust in city/state/federal agencies. Community will not trust. Ebola is an example of how far things got out of control. Public perception is unbelievable. Flint residents still not drinking the water. Education is the key for gaining trust. NCRP conference had a lot to do with messaging. Most was on shelter in place. People don't understand that the dose makes the poison. They don't care about, and don't understand the threshold. Need to be prepared for people to not follow the rules. Anecdote of Mayor of Japanese village 30 km away from last waive of contamination zone: Mayor got information from public TV – he was mad that no one contacted him to order the evacuation, and used his contacts to gather up Health Physicists and he listened to them. He used money to purchase dosimeters and did not evacuate. The village people started to listen to him and not other messages. Village recovered better than others. The trust in this case came from the beginning. What should a technical person trying to help do? His advice was you need available experts. So, lessons were to be available and communicate with potential key players (OSCs, fire department). Need to understand what the other party's role and responsibilities are and what they are missing.

	DHS S&T is working with FEMA to do sort of what was said. Need for additional health physicist/health physics knowledge throughout the response but also in situations that may not be specific to a rad response, but require solid interpretation of data, understanding of data, or working with decision makers. ROSS (radiological operations support specialist) will be available by request. Goal: Identify training and tools that people could have around the country. Hopefully, FEMA offers a course in next couple of months in Nevada. H**ave to start with trust - be upfront and honest.** This takes training, information, etc. For the Ebola response, the message was: you have to trust me to train you to handle this… and be in the equipment. Have to have a unified message for the people. The three pillars of this scenario are personality, resources, and technology, but underneath are communication and trust: pillars don't work without it. If something were to happen today, and the dose is knocked down by 20-30%, then people might want to stay and clean up homes themselves. We are then going to have a situation where they do generate known radioactive waste above thresholds. How are we going to deal with that? Do we stage like the Japanese? Create additional problems? Is that going to make the situation worse? The evacuation will be made in the first hours. That is when to determine who can stay and who can go. People living there – we can't stop but have to give best advice. Feedback from the UK included: • It is difficult to envisage a scenario where a family/public will be present in an area if the radiation/contamination levels are such that the waste will generate a significant secondary hazard to others. • Can use normal waste bins and then monitor each truck load for gross contamination and then manage that. • In densely populated areas it might be better to use covered municipal skips (allow for the employment of SQEP monitoring personnel at a later date when there is a reduced demand). • There is no effective way to prevent individuals pouring potentially contaminated liquids down the drains. (If activity levels in homes are at a level where that would be an issue, they should have been evacuated long before.) • Standard refuse wagons could be used to collect wastes, though the effect of their compactors re-suspending activity would have to be considered.

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Any large vehicle for carrying bulk materials could be considered, i.e., waste skip lorries, flat bed tipper trucks, quarry wagons, etc. These could be loaded either by hand (the residents) or by tractor and bucket.
If the amount of waste generated from each household can be reasonably estimated, then suitable waste containers can be provided to each address. This would make collection of waste a simpler task if all containers were regular sizes.
Issues to consider:

Will it be the container or the vehicle that is considered to be the transport package? If all containers are regular and rated as transport packages (e.g., 50-liter drums or Pactec bags), then either is fine, but if items are disposed of wrapped in shopping bags, for example, then the vehicle would need to be considered the transport package.
Can regular heavy goods vehicles be used or even a typical recycling collection truck? Can regular refuse disposal teams or parcel delivery teams be used with some training and HP support? This is probably dependent on waste container type. Regular garbage or parcel delivery teams would know the area, the routes that are accessible by truck, and SQEP available for manual handling, and HP support would be aware of the radiological hazards.
Is a 50-liter container big enough or is a 200-liter drum more realistic? Bigger containers would have more manual handling issues for residents and waste collectors.
Can waste containers be filled, moved, stored, and collected easily in congested downtown areas? It is likely that while more rural areas may have more land to clean up, they would have more space to work. Waste containers could be stored more safely in rural areas with lower ambient doses.
How would cleanup efforts and waste collection work with apartment block residents or renters of property? These categories of resident would probably be more reluctant to participate in cleanup work, relying on apartment block managers and property owners to perform the work.

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<tr><td>Scenario 2: How would the answer to Scenario 1 above differ if the radioactively contaminated material is being generated by local businesses as a result of self-help decontamination practices? How would the individual waste receptacles generated by local businesses be collected to avoid an accumulation of radioactively contaminated</td><td>
Workshop participants were instructed to provide input later

Feedback from the UK included:

Same as above. Businesses can be more easily incentivized and held accountable for correct disposal of such waste than individuals.
Businesses tend to have large waste containers for normal refuse. As a start, these could be used with the frequency of collection increased. In addition, waste skips, ISO containers, etc., could be used.

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materials in multi-business units or at the curbside? Does the equipment and method of collection differ for more sparsely distributed suburban areas as opposed to congested downtown businesses?	
Scenario 3: If the accumulated radioactively contaminated waste is being collected at staging locations (for example, parks and common grounds), what types of containers can be used to collect the waste receptacles and protect the public from transport of contaminated particles (for example, through resuspension of breached receptacles)?	*Workshop participants were instructed to provide input later* Feedback from the UK included: • Easily sealable containers would be used, e.g., ISO freight containers (lockable), skips (lockable), steel drums (which are not easily opened after sealing without tools). • Liquid waste could be pumped into intermediate bulk containers, large steel tanks, or temporarily constructed lagoons. • Staging locations could be town halls, a sports stadium, or postal depots. These would be accessible areas with car parking and covered overhead. They would provide the opportunity for structured processing facilities perhaps with waste characterization capability (e.g., a turntable portable gamma spectrometer).
Scenario 4: Do you have other thoughts or specific questions based on your experiences in your geographical area related to this topic?	*Workshop participants were instructed to provide input later* Feedback from the UK included: • In certain geographical areas, wind and rain would be an issue.... Another consideration could be that the local road network quickly gridlocks with heavy traffic. - Bagging up of unlabeled waste in non-transparent bags means a lengthy double handling and monitoring process to establish appropriate waste routes and activities. - Not understanding the waste container requirements during generation of waste leads to an inevitable re-sizing process to make waste fit new containers. - Using containers that are not fit for transport or disposal means providing overpacks or specialist transport when transport or disposal is required. • The amount of waste generated can be far in excess of that expected, so overkill on waste facility design is no bad thing. • Running a waste facility is a complex task.
Support Goal Training: Wide-area radiological contamination incidents are rare, and a response to such an incident will require tremendous human assets. We learned from the cleanup efforts in Japan that many thousands of individuals each	*Workshop participants were instructed to provide input later* Feedback from the UK included: • UK legislation requires employers to ensure their workforce are suitably trained for any tasks they are required to perform.

day are engaged in clean-up activities. What are your thoughts and recommendations on availability of trained human assets and training of additional assets that will likely be needed in order to accomplish the scenarios under this goal? (Note: We realize that training will be a significant effort and an additional limiting factor in any response scenario. Further, it may need to be addressed more thoroughly in the future, but we would like input to help guide how we should continue toward developing training guidance.)	• Training on waste minimization and radiation safety would allow members of the public to make an effective contribution to the clean-up operations.

Scenario Description: Containment of Water, Wastewater, and Other Wastes	**Scenario Response (Please provide specific ways in which you would respond to the scenario and what types of equipment you would require. Please use NIMS typing if it is available and you are familiar with the FEMA NIMS system.) Note: Below includes returned responses and responses captured during the Workshop.**
Scenario 1: What types of barriers (for example, sandbags and berms) are available to collect water that is generated during its large-scale use (hundreds of thousands to millions of gallons) over a small urban footprint (for example, 1 square city block)?	As part of the I-Water Systems, emergency collapsible berms are used around the world for flood control and US Troops. They come in impermeable and permeable materials. They have been used instead of sands bags and are easier to deploy with one operator. Bunds are like socks and are a way to move/divert low volumes of water. Anything we say about barriers does not apply to emergency activities (improvised nuclear device and nuclear power plant incident). You have to use the firehose to wash people and water will go down street. On a large scale, we have to use the natural topography, contours, storm sewer to collect/divert water. Fire units have berms, etc., for smaller scenarios so they drop drain covers and contain, but if a significant amount moves into sewers, they notify the water plants. The water district can divert and use bladders to plug the system to hold water until later. If combined sewers are in place, this is possible. For others, the water moves to streams, etc. In a chemical event, we will drop drain covers as best as we can to not allow water in sewer system. We need to be able to apply copious amounts of water on fire before use of foam. The reality is that most water is going into the sewer system, but firefighters do try to isolate. Containing water at factories is a little easier because they have berms onsite. Firefighters do test the water with chemically reactive strips, and do air monitoring for special events. This is done for situational awareness but also to get the right agencies involved afterwards. In a situation where a large amount of contaminated water has gone in the sewer system, what can be done? We can divert the water sometimes, can put huge bladders in, and plug the system so that water builds up in piping. Keep in mind that most places do not have combined sewer, and it is going to go into water system downstream. Whether the water goes into a combined sewer or flows into a storm water system, whatever the system is, it is going to be contaminated. Most treatment facilities have the ability to divert their inflow around the plant to control levels or to do maintenance (shutdown and bypass). [Conversations with Chicago Water Reclamation District revealed that plugging sewer piping leads to flooding in known low-lying areas of the sewer system. This may present problems to these locations. Also, the current sewer system does not have bladders specifically designed to divert a flow of water to protect the waste reclamation plants.] Problems can be created when a plant is shut down.

	Representatives from water treatment facilities should be invited to the next Workshop. [Author MDK met with the Chicago Metropolitan Water Reclamation District to discuss wastewater problem. There may be a way to implement a real-time treatment option that utilizes existing unit operations. However, use of a plugging system and/or diverting water cannot be done without re-piping or studies to look at plugging options. The solution is not straightforward or immediately identifiable.] For emergency response, the fire department is going to do what they need to do. For cleanup, we will need to work with the sewer authority. Chief mentioned they have good relations with the water authority. The State will be coordinating with the solid waste authority. It was reiterated that a different approach is needed for short- and long-term scenarios. In the short term, it is hard to control the movement of water, but in the long term we can come up with engineered solutions: creating and managing the environment to handle the water. Is it feasible to design a drain system? A piping system could be set up to carry contained water to a reservoir for treatment. Any civil engineer could do this. Should keep in mind that this is based on the assumption that facilities are working the way they should. But, what about major disruptions in the water structures? They might not even be operational. Low-level radiation may not kill the bacteria in plant, but it may need to be removed from the sludge –where it might be concentrated. Feedback from the UK included: • Collection of water from decontamination of buildings, paved areas and roads could be accomplished through a couple of methods: 1) Drains could be protected/covered to prevent run-off of water to municipal drainage systems and then berms/bunding/plastic sheeting combined with sandbags or gravel filled bags could be used to contain water, which could then be pumped into tankers for transport. 2) A similar method could be set up as above, but with volumes of waste water requiring management reduced through use of lower pressure jetting. • Typical berms and bunds are designed to minimize the impact of spillages rather than control large quantities of contaminated water. Drain covers are similarly designed to provide a few hours of protection while spillages are brought under control. Unsure if these can be used effectively to control millions of gallons of water

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<tr><td>Scenario 2: What types of barriers (for example, sandbags and berms) are available to collect water that is generated during its large-scale use (millions of gallons) over a large urban footprint (for example, 10 square city blocks)?</td><td>Similar to above.

Feedback from the UK included:
Similar to scenario 1 but larger barriers or more of them.
Likely the most effective way to manage water on this scale, aside from dividing it up into more manageable areas, is to use existing municipal drainage and suitably funnel or treat the water inside the drainage system.
Commercially available portable spill containment systems available with sizes up to 25,000 gallons (lead times to procurement?)</td></tr>
<tr><td>Scenario 3: Do the answers to Scenario 1 and 2 above differ if the water is used to wash down vertical as opposed to horizontal surfaces?</td><td>Use the topography to find the low spot and try to contain. Start at the top with a wash down, then remove the soil afterward.

If critical infrastructure does not follow topography, then just need to get area clean enough to open for operations. May have to have those working there trained in Rad. May have to clean it multiple times. Will most likely use berms or basins. A lot of civil engineers do not have experience in this type of contamination.

What is the feasibility of using window cleaning companies?

New buildings are likely to have a very high decontamination factor, and it may be sufficient to reopen business. Will there be enough vacuum trucks? Vacuum trucks are all over. More in rural area - used to pump septic system. Should not be a problem for a planned operation. The group was not aware of exactly how to decontaminate a vacuum truck, but the UK did decontaminate road sweepers used for dry sweeping at Maralinga.

The fire hydrant systems are under the water department authority, not the fire department. The Chicago Fire Department does a flow test on hydrants in October. Street sweepers use hydrants after that. Sewer systems have rain water restrictors to keep water at slow flow in drains, it floods streets, but keeps basements from flooding.

Contractors can hook up to hydrants to knock down dust when demolishing buildings. Must obtain permit from city. CSTs are trained to understand what fire services do and can do hazardous material responses with the fire department. In Chicago, CSTs gets hydrant wrenches if they need to open them up.
Some companies fill up swimming pools all at once.</td></tr>
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	Feedback from the UK included: • Collection from vertical wall surfaces is difficult in an uncontrolled environment as forming a seal between wall and collecting vessel varies according to surface type.
Scenario 4: If the water is collected at the point of use, what containers/vessels/facilities are available to store the water generated in Scenarios 1-3 until it can be processed or transported?	CST members have training to open hydrants to decontaminate personnel and have bunds to collect water. Feedback from the UK included: Any large, sealed container would be suitable, subject to risk assessment and structural integrity requirements. Also, 1) Large steel tanks (similar to those used at Fukushima) 2) IBCs 3) Road tankers (which would allow for immediate transport following filling) 4) Locally constructed lagoons or pools. It may be necessary to build temporary "lagoons" to store large volumes of water prior to transport. Digging pits and lining with plastic sheeting would provide a large volume holding area for the short term.
Scenario 5: If the water penetrates the sewer system and can be diverted at a downstream collection site (for example, just prior to entering the water reclamation district or wastewater treatment plant), what containers/vessels/facilities are available to store the water until it can be processed or transported?	Could use large tanks and barges, but could also do construction of lagoons, and those could be lined until treated, or can build a pipe to reservoir (mentioned earlier). Feedback from the UK included: Realistically, very large steel tanks or temporarily constructed "lagoons" would be required to take and store as much water as would likely be diverted from the drainage system.
Scenario 6: If we wish to avoid the sewer system, what other methods of diverting water are available to collect water at a central location?	***Workshop participants were instructed to provide input later*** Feedback from the UK included: • Channels or piping could be emplaced as a type of temporary drainage alternative. These may require pumps but could be used to transport water directly to lagoons or storage tanks. It may even be possible to line existing drainage systems with piping, allowing for use of existing channels without contaminating the drainage pipes themselves. • Storm-water bunding systems typically have inflatable tubes that could be used to direct water.

Scenario 7: Are there existing trench, dam, retention ponds, community reservoirs, etc., available to collect water and are there paths for directing the wash water from its point of use to these existing collection systems?	*Workshop participants were instructed to provide input later* Feedback from the UK included: • Whilst water could be piped to these locations using temporary piping or transported via tanker it may be more efficient to use municipal drainage system subject to suitable risk assessment and management by drainage companies. This could take many forms, from allowing water to flow along normal routes to shutting off drainage routes and funneling all of the water along a specific path and concentrating it in one location for collection/treatment. • Underground parking garages have been designed and used in other countries to store floodwater.
Scenario 8: Do you have other thoughts or specific questions based on your experiences in your geographical area related to this topic?	*Workshop participants were instructed to provide input later* Feedback from the UK included: • If funds were available research into the temporary storage and filtering of large volumes of liquid waste should be a priority. This filtering could be done at strategic points along the drainage system before waters reach critical infrastructure, rivers, or the sea.
Support Goal Training: Wide-area radiological contamination incidents are rare, and a response to such an incident will require tremendous human assets. We learned from the cleanup efforts in Japan that many thousands of individuals each day are engaged in clean-up activities. What are your thoughts and recommendations on availability of trained human assets and training of additional assets that will likely be needed in order to accomplish the scenarios under this goal? (Note: We realize that training will be a significant effort and an additional limiting factor in any response scenario. Further, it may need to be addressed more thoroughly in the future, but we would like input to help guide how we should continue toward developing training guidance.)	*Workshop participants were instructed to provide input later* Feedback from the UK included: Large-scale wastewater management would require specialist floodwater management expertise supported by health physics monitors and decommissioning engineers.

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